Cytec Cycom 5215 T40-800 Unitape Gr 145 33% RC Qualification Statistical Analysis Report

DISCONTINUED

FAA Special Project Number SP4612WI-Q

Report Release Date: August 1, 2012

NCAMP Test Report Number: NCP-RP-2010-037 N/C

Elizabeth Clarkson, Ph.D.
National Center for Advanced Materials Performance (NCAMP)
National Institute for Aviation Research
Wichita State University
Wichita, KS 67260-0093

Testing Facility:

National Institute for Aviation Research
Wichita State University
1845 N. Fairmount
Wichita, KS 67260-0093

Test Panel Fabrication Facility:

Cytec Engineered Materials
1440 N. Kraemer Blvd
Anaheim, CA 92806

Prepared by:________________________
Elizabeth Clarkson, Ph.D

Reviewed by:____________ ____________________
Evelyn Lian **Michelle Man**

Approved by:__________________
Yeow Ng

DISCONTINUED

REVISIONS:

Rev	By	Date	Rev App By	Pages Revised or Added
N/C	Elizabeth Clarkson	08/01/2012	Yeow Ng	Document Initial Release

Table of Contents

List of Figures

List of Tables

1. Introduction

This report contains statistical analysis of the Cytec 5215 T40-800 Unidirectional material property data published in NCAMP Test Report CAM-RP-2010-048 N/C. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP4612WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP100 and NCAMP Process Specification NSP 81323 Rev A dated July 16, 2007. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

B-Basis values, A-estimates, and B-estimates were calculated using a variety of techniques that are detailed in section two. The qualification material was procured to NCAMP Material Specification NMS 323/1 Rev A dated July 16, 2007. The qualification test panels were fabricated per NCAMP Process Specification NPS 81323 Rev A dated July 16, 2007. The panels were fabricated by Cytec Engineered Materials at 1440 N. Kraemer Blvd, Anaheim, CA 92806. The NCAMP Test Plan NTP 3668Q1 Rev. A was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

Basis numbers are labeled as ‘values’ when the data meets all the requirements of working draft CMH-17 Rev G. When those requirements are not met, they will be labeled as ‘estimates.’ When the data does not meet all requirements, the failure to meet these requirements is reported and the specific requirement(s) the data fails to meet is identified. The method used to compute the basis value is noted for each basis value provided. When appropriate, in addition to the traditional computational methods, values computed using the modified coefficient of variation method is also provided.

The material property data acquisition process is designed to generate basic material property data with sufficient pedigree for submission to Complete Documentation sections of the Composite Materials Handbook (working draft CMH-17 Rev G).

The NCAMP shared material property database contains material property data of common usefulness to a wide range of aerospace projects. However, the data may not fulfill all the needs of a project. Specific properties, environments, laminate architecture, and loading situations that individual projects need may require additional testing.

The use of NCAMP material and process specifications do not guarantee material or structural performance. Material users should be actively involved in evaluating material performance and quality including, but not limited to, performing regular purchaser quality control tests, performing periodic equivalency/additional testing, participating in material change management activities, conducting statistical process control, and conducting regular supplier audits.

The applicability and accuracy of NCAMP material property data, material allowables, and specifications must be evaluated on case-by-case basis by aircraft companies and certifying agencies. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables, and specifications.

Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of working draft CMH-17 Rev G. The applicability of equivalency process must be evaluated on program-by-program basis by the applicant and certifying agency. The applicant and certifying agency must agree that the equivalency test plan along with the equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of working draft CMH-17 Rev G are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 323/1. NMS 323/1 has additional requirements that are listed in its prepreg process control document (PCD), fiber specification, fiber PCD, and other raw material specifications and PCDs which impose essential quality controls on the raw materials and raw material manufacturing equipment and processes. *Aircraft companies and certifying agencies should assume that the material property data published in this report is not applicable when the material is not procured to NCAMP Material Specification NMS 323/1. NMS 323/1* is a free, publicly available, non-proprietary aerospace industry material specification.

This report is intended for general distribution to the public, either freely or at a price that does not exceed the cost of reproduction (e.g. printing) and distribution (e.g. postage).

1.1 Symbols and Abbreviations

Test Property	Abbreviation
Longitudinal Compression	LC
Longitudinal Tension	LT
Transverse Compression	TC
Transverse Tension	TT
In-Plane Shear	IPS
Short Beam Strength	SBS
Laminate Short Beam Strength	SBS1
Unnotched Tension	UNT
Unnotched Compression	UNC
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Open Hole Tension	OHT
Open Hole Compression	OHC
Single Shear Bearing	SSB
Interlaminar Tension	ILT
Curved Beam Strength	CBS
Compression After Impact	CAI

Table 1-1: Test Property Abbreviations

Test Property	Symbol
Longitudinal Compression Strength	F_1^{cu}
Longitudinal Compression Modulus	E_1^{c}
Longitudinal Compression Poisson’s Ratio	ν_{12}^{c}
Longitudinal Tension Strength	F_1^{tu}
Longitudinal Tension Modulus	E_1^{t}
Longitudinal Tension Poisson’s Ratio	ν_{12}^{t}
Transverse Compression Strength	F_2^{cu}
Transverse Compression Modulus	E_2^{c}
Transverse Compression Poisson’s Ratio	ν_{21}^{c}
Transverse Tension Strength	F_2^{tu}
Transverse Tension Modulus	E_2^{t}
In-Plane Shear Peak Strength before 5% strain	$F_{12}^{s\ max}$
In-Plane Shear Strength at 5% strain	$F_{12}^{s5\%}$
In-Plane Shear Strength at 0.2% offset	$F_{12}^{s0.2\%}$
In-Plane Shear Modulus	G_{12}^{s}

Table 1-2: Test Property Symbols

Environmental Condition	Abbreviation	Temperature
Cold Temperature Dry	CTD	−65°F
Room Temperature Dry	RTD	70°F
Elevated Temperature Dry	ETD	180°F
Elevated Temperature Wet	ETW	180°F

Table 1-3: Environmental Conditions Abbreviations

Tests with a number immediately after the abbreviation indicate the lay-up:

1 refers to a 25/50/25 layup. This is also referred to as "Quasi-Isotropic"
2 refers to a 10/80/10 layup. This is also referred to as “Soft”
3 refers to a 50/40/10 layup. This is also referred to as “Hard”

EX: OHT1 is an open hole tension test with a 25/50/25 layup

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2010-048 N/C.

1.2 Pooling Across Environments

When pooling across environments was allowable, the pooled co-efficient of variation was used. ASAP (**A**GATE **S**tatistical **A**nalysis **P**rogram) 2008 version 1.0 was used to determine if pooling was allowable and to compute the pooled coefficient of variation for those tests. In these cases, the modified coefficient of variation based on the pooled data was used to compute the basis values.

When pooling across environments was not advisable because the data was not eligible for pooling and engineering judgment indicated there was no justification for overriding the result, then B-Basis values were computed for each environmental condition separately using Stat17 version 5.

1.3 Basis Value Computational Process

The general form to compute engineering basis values is: basis value = $\bar{X} - kS$ where k is a factor based on the sample size and the distribution of the sample data. There are many different methods to determine the value of *k* in this equation, depending on the sample size and the distribution of the data. In addition, the computational formula used for the standard deviation, S, may vary depending on the distribution of the data. The details of those different computations and when each should be used are in section 2.0.

1.4 Modified Coefficient of Variation (CV) Method

A common problem with new material qualifications is that the initial specimens produced and tested do not contain all of the variability that will be encountered when the material is being produced in larger amounts over a lengthy period of time. This can result in setting basis values that are unrealistically high. The variability as-measured in the qualification program is often lower than the actual material variability because of several reasons. The materials used in the qualification programs are usually manufactured within a short period of time, typically 2-3 weeks only, which is not representative of the production material. Some raw ingredients that are used to manufacture the multi-batch qualification materials may actually be from the same production batches or manufactured within a short period of time so the qualification materials, although regarded as multiple batches, may not truly be multiple batches so they are not representative of the actual production material variability.

The modified Coefficient of Variation (CV) used in this report is in accordance with section 8.4.4 of working draft CMH-17 Rev G. It is a method of adjusting the original basis values downward in anticipation of the expected additional variation. Composite materials are expected to have a CV of at least 6%. The modified coefficient of variation (CV) method increases the measured coefficient of variation when it is below 8% prior to computing basis values. A higher CV will result in lower or more conservative basis values and lower specification limits. The use of the modified CV method is intended for a temporary period of time when there is minimal data available. When a sufficient number of production batches (approximately 8 to 15) have been produced and tested, the as-measured CV may be used so that the basis values and specification limits may be adjusted higher.

The material allowables in this report are calculated using both the as-measured CV and modified CV, so users have the choice of using either one. When the measured CV is greater than 8%, the modified CV method does not change the basis value. NCAMP recommended values make use of the modified CV method when it is appropriate for the data.

When the data fails the Anderson-Darling K-sample test for batch to batch variability or when the data fails the normality test, the modified CV method is not appropriate and no modified CV basis value will be provided. When the ANOVA method is used, it may produce excessively conservative basis values. When appropriate, a single batch or two batch estimate may be provided in addition to the ANOVA estimate.

In some cases a transformation of the data to fit the assumption of the modified CV resulted in the transformed data passing the ADK test and thus the data can be pooled only for the modified CV method.

NCAMP recommends that if a user decides to use the basis values that are calculated from as-measured CV, the specification limits and control limits be calculated with as-measured CV also. Similarly, if a user decides to use the basis values that are calculated from modified CV, the specification limits and control limits be calculated with modified CV also. This will ensure that the link between material allowables, specification limits, and control limits is maintained.

2. Background

Statistical computations are performed with AGATE Statistical Analysis Program (ASAP) when pooling across environments is permissible according to working draft CMH-17 Rev G guidelines. If pooling is not permissible, a single point analysis using STAT-17 is performed for each environmental condition with sufficient test results. If the data does not meet working draft CMH-17 Rev G requirements for a single point analysis, estimates are created by a variety of methods depending on which is most appropriate for the dataset available. Specific procedures used are presented in the individual sections where the data is presented.

2.1 ASAP Statistical Formulas and Computations

This section contains the details of the specific formulas ASAP uses in its computations.

2.1.1 Basic Descriptive Statistics

The basic descriptive statistics shown are computed according to the usual formulas, which are shown below:

Mean: $$\bar{X} = \sum_{i=1}^{n} \frac{X_i}{n}$$ **Equation 1**

Std. Dev.: $$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}$$ **Equation 2**

% Co. Variation: $$\frac{S}{\bar{X}} \times 100$$ **Equation 3**

Where n refers to the number of specimens in the sample and X_i refers to the individual specimen measurements.

2.1.2 Statistics for Pooled Data

Prior to computing statistics for the pooled dataset, the data is normalized to a mean of one by dividing each value by the mean of all the data for that condition. This transformation does not affect the coefficients of variation for the individual conditions.

2.1.2.1 Pooled Standard Deviation

The formula to compute a pooled standard deviation is given below:

Pooled Std. Dev. $$S_p = \sqrt{\frac{\sum_{i=1}^{k}\left(n_i - 1\right) S_i^2}{\sum_{i=1}^{k}\left(n_i - 1\right)}}$$ **Equation 4**

Where k refers to the number of batches, S_i indicates the standard deviation of i^{th} sample, and n_i refers to the number of specimens in the i^{th} sample.

2.1.2.2 Pooled Coefficient of Variation

Since the mean for the normalized data is 1.0 for each condition, the pooled normalized data also has a mean of one. The coefficient of variation for the pooled normalized data is the pooled standard deviation divided by the pooled mean, as in equation 3. Since the mean for the pooled normalized data is one, the pooled coefficient of variation is equal to the pooled standard deviation of the normalized data.

$$\textbf{Pooled Coefficient of Variation} = \frac{S_p}{1} = S_p \qquad \textbf{Equation 5}$$

2.1.3 Basis Value Computations

Basis values are computed using the mean and standard deviation for that environment, as follows: The mean is always the mean for the environment, but if the data meets all requirements for pooling, S_p can be used in place of the standard deviation for the environment, S.

Basis Values:

$$A-basis = \bar{X} - K_a S$$
$$B-basis = \bar{X} - K_b S \qquad \textbf{Equation 6}$$

2.1.3.1 K-factor computations

K_a and K_b are computed according to the methodology documented in section 8.3.5 of working draft CMH-17 Rev G. The approximation formulas are given below:

$$K_a = \frac{2.3263}{\sqrt{q(f)}} + \sqrt{\frac{1}{c_A(f)\cdot n_j} + \left(\frac{b_A(f)}{2c_A(f)}\right)^2} - \frac{b_A(f)}{2c_A(f)} \qquad \textbf{Equation 7}$$

$$K_b = \frac{1.2816}{\sqrt{q(f)}} + \sqrt{\frac{1}{c_B(f)\cdot n_j} + \left(\frac{b_B(f)}{2c_B(f)}\right)^2} - \frac{b_B(f)}{2c_B(f)} \qquad \textbf{Equation 8}$$

Where

r = the number of environments being pooled together
n_j= number of data values for environment j

$$N = \sum_{j=1}^{r} n_j$$

$$f = N - r$$

$$q(f) = 1 - \frac{2.323}{\sqrt{f}} + \frac{1.064}{f} + \frac{0.9157}{f\sqrt{f}} - \frac{0.6530}{f^2} \qquad \textbf{Equation 9}$$

$$b_B(f) = \frac{1.1372}{\sqrt{f}} - \frac{0.49162}{f} + \frac{0.18612}{f\sqrt{f}}$$ **Equation 10**

$$c_B(f) = 0.36961 + \frac{0.0040342}{\sqrt{f}} - \frac{0.71750}{f} + \frac{0.19693}{f\sqrt{f}}$$ **Equation 11**

$$b_A(f) = \frac{2.0643}{\sqrt{f}} - \frac{0.95145}{f} + \frac{0.51251}{f\sqrt{f}}$$ **Equation 12**

$$c_A(f) = 0.36961 + \frac{0.0026958}{\sqrt{f}} - \frac{0.65201}{f} + \frac{0.011320}{f\sqrt{f}}$$ **Equation 13**

2.1.4 Modified Coefficient of Variation

The coefficient of variation is modified according to the following rules:

Modified CV = $$CV^* = \begin{cases} .06 & if\ CV < .04 \\ \frac{CV}{2} + .04 & if\ .04 \le CV < .08 \\ CV & if\ CV \ge .08 \end{cases}$$ **Equation 14**

This is converted to percent by multiplying by 100%.

CV^* is used to compute a modified standard deviation S^*.

$$S^* = CV^* \cdot \bar{X}$$ **Equation 15**

To compute the pooled standard deviation based on the modified CV:

$$S_p^* = \sqrt{\frac{\sum_{i=1}^{k}\left((n_i - 1)\left(CV_i^* \cdot \bar{X}_i\right)^2\right)}{\sum_{i=1}^{k}(n_i - 1)}}$$ **Equation 16**

The A-basis and B-basis values under the assumption of the modified CV method are computed by replacing S with S^*

2.1.4.1 Transformation of data based on Modified CV

In order to determine if the data would pass the diagnostic tests under the assumption of the modified CV, the data must be transformed such that the batch means remain the same while the standard deviation of transformed data (all batches) matches the modified standard deviation.

To accomplish this requires a transformation in two steps:

Step 1: Apply the modified CV rules to each batch and compute the modified standard deviation $S_i^* = CV^* \cdot \bar{X}_i$ for each batch. Transform the individual data values (X_{ij}) in each batch as follows:

$$X'_{ij} = C_i\left(X_{ij} - \bar{X}_i\right) + \bar{X}_i \qquad \textbf{Equation 17}$$

$$C_i = \frac{S_i^*}{S_i} \qquad \textbf{Equation 18}$$

Run the Anderson-Darling k-sample test for batch equivalence (see section 2.1.6) on the transformed data. If it passes, proceed to step 2. If not, stop. The data cannot be pooled.

Step 2: Another transformation is needed as applying the modified CV to each batch leads to a larger CV for the combined data than when applying the modified CV rules to the combined data (due to the addition of between batch variation when combining data from multiple batches). In order to alter the data to match S^*, the transformed data is transformed again, this time setting using the same value of C′ for all batches.

$$X''_{ij} = C'\left(X'_{ij} - \bar{X}_i\right) + \bar{X}_i \qquad \textbf{Equation 19}$$

$$C' = \sqrt{\frac{SSE^*}{SSE'}} \qquad \textbf{Equation 20}$$

$$SSE^* = (n-1)\left(CV^* \cdot \bar{X}\right)^2 - \sum_{i=1}^{k} n_i\left(\bar{X}_i - \bar{X}\right)^2 \qquad \textbf{Equation 21}$$

$$SSE' = \sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(X'_{ij} - \bar{X}_i\right)^2 \qquad \textbf{Equation 22}$$

Once this second transformation has been completed, the k-sample Anderson Darling test for batch equivalence can be run on the transformed data to determine if the modified co-efficient of variation will permit pooling of the data.

2.1.5 Determination of Outliers

All outliers are identified in text and graphics. If an outlier is removed from the dataset, it will be specified and the reason why will be documented in the text. Outliers are identified using the Maximum Normed Residual Test for Outliers as specified in section 8.3.3 of working draft CMH-17 Rev G.

$$MNR = \frac{\max\limits_{all\ i}\left|X_i - \bar{X}\right|}{S},\ i = 1 \ldots n \qquad \textbf{Equation 23}$$

$$C = \frac{n-1}{\sqrt{n}}\sqrt{\frac{t^2}{n-2+t^2}} \qquad \textbf{Equation 24}$$

where t is the $1-\frac{.05}{2n}$ quartile of a t distribution with n−2 degrees of freedom, n being the total number of data values.

If MNR > C, then the X_i associated with the MNR is considered to be an outlier. If an outlier exists, then the X_i associated with the MNR is dropped from the dataset and the MNR procedure is applied again. This process is repeated until no outliers are detected. Additional information on this procedure can be found in references 1 and 2.

2.1.6 The k-Sample Anderson Darling Test for Batch Equivalency

The k-sample Anderson-Darling test is a nonparametric statistical procedure that tests the hypothesis that the populations from which two or more groups of data were drawn are identical. The distinct values in the combined data set are ordered from smallest to largest, denoted $z_{(1)}, z_{(2)}, \ldots z_{(L)}$, where L will be less than n if there are tied observations. These rankings are used to compute the test statistic.

The k-sample Anderson-Darling test statistic is:

$$ADK = \frac{n-1}{n^2(k-1)}\sum_{i=1}^{k}\left[\frac{1}{n_i}\sum_{j=1}^{L}h_j\frac{\left(nF_{ij}-n_iH_j\right)^2}{H_j\left(n-H_j\right)-\frac{nh_j}{4}}\right] \quad \textbf{Equation 25}$$

Where

n_i = the number of test specimens in each batch
$n = n_1+n_2+\ldots+n_k$
h_j = the number of values in the combined samples equal to $z_{(j)}$
H_j = the number of values in the combined samples less than $z_{(j)}$ plus ½ the number of values in the combined samples equal to $z_{(j)}$
F_{ij} = the number of values in the i^{th} group which are less than $z_{(j)}$ plus ½ the number of values in this group which are equal to $z_{(j)}$.

The critical value for the test statistic at 1−α level is computed:

$$ADC = 1+\sigma_n\left[z_\alpha+\frac{0.678}{\sqrt{k-1}}-\frac{0.362}{k-1}\right]. \quad \textbf{Equation 26}$$

This formula is based on the formula in reference 3 at the end of section 5, using a Taylor's expansion to estimate the critical value via the normal distribution rather than using the t distribution with k-1 degrees of freedom.

$$\sigma_n^2 = VAR(ADK) = \frac{an^3+bn^2+cn+d}{(n-1)(n-2)(n-3)(k-1)^2} \quad \textbf{Equation 27}$$

With

$$a = (4g-6)(k-1) + (10-6g)S$$
$$b = (2g-4)k^2 + 8Tk + (2g-14T-4)S - 8T + 4g - 6$$
$$c = (6T+2g-2)k^2 + (4T-4g+6)k + (2T-6)S + 4T$$
$$d = (2T+6)k^2 - 4Tk$$
$$S = \sum_{i=1}^{k} \frac{1}{n_i}$$
$$T = \sum_{i=1}^{n-1} \frac{1}{i}$$
$$g = \sum_{i=1}^{n-2} \sum_{j=i+1}^{n-1} \frac{1}{(n-i)j}$$

The data is considered to have failed this test (i.e. the batches are not from the same population) when the test statistic is greater than the critical value. For more information on this procedure, see reference 3.

2.1.7 The Anderson Darling Test for Normality

Normal Distribution: A two parameter (μ, σ) family of probability distributions for which the probability that an observation will fall between *a* and *b* is given by the area under the curve between a and b:

$$F(x) = \int_a^b \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx \qquad \textbf{Equation 28}$$

A normal distribution with parameters (μ, σ) has population mean μ and variance σ^2.

The normal distribution is considered by comparing the cumulative normal distribution function that best fits the data with the cumulative distribution function of the data. Let

$$z_{(i)} = \frac{x_{(i)} - \bar{x}}{s}, \quad \text{for i = 1,…,n} \qquad \textbf{Equation 29}$$

where $x_{(i)}$ is the smallest sample observation, $\bar{x}$ is the sample average, and s is the sample standard deviation.

The Anderson Darling test statistic (AD) is:

$$AD = \sum_{i=1}^{n} \frac{1-2i}{n} \left\{ \ln\left[F_0(z_{(i)})\right] + \ln\left[1 - F_0\left(z_{(n+1-i)}\right)\right] \right\} - n \qquad \textbf{Equation 30}$$

Where F_0 is the standard normal distribution function. The observed significance level (OSL) is

$$OSL = \frac{1}{1 + e^{-0.48 + 0.78\ln(AD^*) + 4.58AD^*}}, \quad AD^* = \left(1 + \frac{0.2}{\sqrt{n}}\right) AD \qquad \textbf{Equation 31}$$

This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if, in fact, the data are a sample from a normal population. If OSL > 0.05, the data is considered sufficiently close to a normal distribution.

2.1.8 Levene's Test for Equality of Coefficient of Variation

Levene's test performs an Analysis of Variance on the absolute deviations from their sample medians. The absolute value of the deviation from the median is computed for each data value. $w_{ij} = \left| y_{ij} - \tilde{y}_i \right|$ An F-test is then performed on the transformed data values as follows:

$$F = \frac{\sum_{i=1}^{k} n_i \left(\overline{w}_i - \overline{w} \right)^2 / (k-1)}{\sum_{i=1}^{k} \sum_{j=1}^{n_i} {}_i \left(w_{ij} - \overline{w}_i \right)^2 / (n-k)}$$

Equation 32

If this computed F statistic is less than the critical value for the F-distribution having k-1 numerator and n-k denominator degrees of freedom at the 1-α level of confidence, then the data is not rejected as being too different in terms of the co-efficient of variation. ASAP provides the appropriate critical values for F at α levels of 0.10, 0.05, 0.025, and 0.01. For more information on this procedure, see references 4 and 5.

2.2 STAT-17

This section contains the details of the specific formulas STAT-17 uses in its computations.

The basic descriptive statistics, the maximum normed residual (MNR) test for outliers, and the Anderson Darling K-sample test for batch variability are the same as with ASAP – see sections 2.1.1, 2.1.3.1, and 2.1.5.

Outliers must be dispositioned before checking any other test results. The results of the Anderson Darling k-Sample (ADK) Test for batch equivalency must be checked. If the data passes the ADK test, then the appropriate distribution is determined. If it does not pass the ADK test, then the ANOVA procedure is the only approach remaining that will result in basis values that meet the requirements of working draft CMH-17 Rev G.

2.2.1 Distribution Tests

In addition to testing for normality using the Anderson-Darling test (see 2.1.7); Stat17 also tests to see if the Weibull or Lognormal distribution is a good fit for the data.

Each distribution is considered using the Anderson-Darling test statistic which is sensitive to discrepancies in the tail regions. The Anderson-Darling test compares the cumulative distribution function for the distribution of interest with the cumulative distribution function of the data.

An observed significance level (OSL) based on the Anderson-Darling test statistic is computed for each test. The OSL measures the probability of observing an Anderson-Darling test statistic at least as extreme as the value calculated if the distribution under consideration is in fact the underlying distribution of the data. In other words, the OSL is the probability of obtaining a value of the test statistic at least as large as that obtained if the hypothesis that the data are actually from the distribution being tested is true. If the OSL is less than or equal to 0.05, then the assumption that the data are from the distribution being tested is rejected with at most a five percent risk of being in error.

If the normal distribution has an OSL greater than 0.05, then the data is assumed to be from a population with a normal distribution. If not, then if either the Weibull or lognormal distributions has an OSL greater than 0.05, then one of those can be used. If neither of these distributions has an OSL greater than 0.05, a non-parametric approach is used.

In what follows, unless otherwise noted, the sample size is denoted by n, the sample observations by $x_1, \ldots, x_n$, and the sample observations ordered from least to greatest by $x_{(1)}, \ldots, x_{(n)}$.

2.2.2 Computing Normal Distribution Basis Values

Stat17 uses a table of values for the k-factors (shown in Table 2-1) when the sample size is less than 16 and a slightly different formula than ASAP to compute approximate k-values for the normal distribution when the sample size is 16 or larger.

Norm. Dist. k Factors for N<16		
N	B-basis	A-basis
2	20.581	37.094
3	6.157	10.553
4	4.163	7.042
5	3.408	5.741
6	3.007	5.062
7	2.756	4.642
8	2.583	4.354
9	2.454	4.143
10	2.355	3.981
11	2.276	3.852
12	2.211	3.747
13	2.156	3.659
14	2.109	3.585
15	2.069	3.520

Table 2-1: K factors for normal distribution

2.2.2.1 One-sided B-basis tolerance factors, k_B, for the normal distribution when sample size is greater than 15.

The exact computation of k_B values is $1/\sqrt{n}$ times the 0.95th quantile of the noncentral t-distribution with noncentrality parameter $1.282\sqrt{n}$ and $n-1$ degrees of freedom. Since this in not a calculation that Excel can handle, the following approximation to the k_B values is used:

$$k_B \approx 1.282 + \exp\{0.958 - 0.520\ln(n) + 3.19/n\} \quad \textbf{Equation 33}$$

This approximation is accurate to within 0.2% of the tabulated values for sample sizes greater than or equal to 16.

2.2.2.2 One-sided A-basis tolerance factors, k_A, for the normal distribution

The exact computation of k_B values is $1/\sqrt{n}$ times the 0.95th quantile of the noncentral t-distribution with noncentrality parameter $2.326\sqrt{n}$ and $n-1$ degrees of freedom (Reference 11). Since this is not a calculation that Excel can handle easily, the following approximation to the k_B values is used:

$$k_A \approx 2.326 + \exp\{1.34 - 0.522\ln(n) + 3.87/n\}$$ **Equation 34**

This approximation is accurate to within 0.2% of the tabulated values for sample sizes greater than or equal to 16.

2.2.2.3 Two-parameter Weibull Distribution

A probability distribution for which the probability that a randomly selected observation from this population lies between a and b $(0 < a < b < \infty)$ is given by

$$e^{-(a/\alpha)^\beta} - e^{-(b/\alpha)^\beta}$$ **Equation 35**

where α is called the scale parameter and β is called the shape parameter.

In order to compute a check of the fit of a data set to the Weibull distribution and compute basis values assuming Weibull, it is first necessary to obtain estimates of the population shape and scale parameters (Section 2.2.2.3.1). Calculations specific to the goodness-of-fit test for the Weibull distribution are provided in section 2.2.2.3.2.

2.2.2.3.1 Estimating Weibull Parameters

This section describes the *maximum likelihood* method for estimating the parameters of the two-parameter Weibull distribution. The maximum-likelihood estimates of the shape and scale parameters are denoted $\hat{\beta}$ and $\hat{\alpha}$. The estimates are the solution to the pair of equations:

$$\hat{\alpha}\hat{\beta}n - \frac{\hat{\beta}}{\hat{\alpha}^{\hat{\beta}-1}}\sum_{i=1}^{n} x_i^{\hat{\beta}} = 0$$ **Equation 36**

$$\frac{n}{\hat{\beta}} - n\ln\hat{\alpha} + \sum_{i=1}^{n}\ln x_i - \sum_{i=1}^{n}\left[\frac{x_i}{\hat{\alpha}}\right]^{\hat{\beta}}\left(\ln x_i - \ln\hat{\alpha}\right) = 0$$ **Equation 37**

Stat17 solves these equations numerically for $\hat{\beta}$ and $\hat{\alpha}$ in order to compute basis values.

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

The two-parameter Weibull distribution is considered by comparing the cumulative Weibull distribution function that best fits the data with the cumulative distribution function of the data. Using the shape and scale parameter estimates from section 2.2.2.3.1, let

$$z_{(i)} = \left[x_{(i)}/\hat{\alpha}\right]^{\hat{\beta}}, \quad \text{for } i = 1, \ldots, n$$ **Equation 38**

The Anderson-Darling test statistic is

$$AD = \sum_{i=1}^{n} \frac{1-2i}{n} \left[\ell n \left[1 - \exp(-z_{(i)}) \right] - z_{(n+1-i)} \right] - n \qquad \textbf{Equation 39}$$

and the observed significance level is

$$OSL = 1/\left\{ 1 + \exp[-0.10 + 1.24 \ln(AD^*) + 4.48 AD^*] \right\} \qquad \textbf{Equation 40}$$

where

$$AD^* = \left(1 + \frac{0.2}{\sqrt{n}} \right) AD \qquad \textbf{Equation 41}$$

This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if in fact the data is a sample from a two-parameter Weibull distribution. If OSL ≤ 0.05, one may conclude (at a five percent risk of being in error) that the population does not have a two-parameter Weibull distribution. Otherwise, the hypothesis that the population has a two-parameter Weibull distribution is not rejected. For further information on these procedures, see reference 6.

2.2.2.3.3 Basis value calculations for the Weibull distribution

For the two-parameter Weibull distribution, the B-basis value is

$$B = \hat{q} e^{\left(-V / \hat{\beta}\sqrt{n} \right)} \qquad \textbf{Equation 42}$$

where

$$\hat{q} = \hat{\alpha} (0.10536)^{1/\hat{\beta}} \qquad \textbf{Equation 43}$$

To calculate the A-basis value, substitute the equation below for the equation above.

$$\hat{q} = \hat{\alpha}(0.01005)^{1/\beta} \qquad \textbf{Equation 44}$$

V is the value in Table 2-2. when the sample size is less than 16. For sample sizes of 16 or larger, a numerical approximation to the V values is given in the two equations immediately below.

$$V_B \approx 3.803 + \exp\left[1.79 - 0.516 \ln(n) + \frac{5.1}{n-1} \right] \qquad \textbf{Equation 45}$$

$$V_A \approx 6.649 + \exp\left[2.55 - 0.526 \ln(n) + \frac{4.76}{n} \right] \qquad \textbf{Equation 46}$$

This approximation is accurate within 0.5% of the tabulated values for n greater than or equal to 16.

Weibull Dist. K Factors for N<16		
N	B-basis	A-basis
2	690.804	1284.895
3	47.318	88.011
4	19.836	36.895
5	13.145	24.45
6	10.392	19.329
7	8.937	16.623
8	8.047	14.967
9	7.449	13.855
10	6.711	12.573
11	6.477	12.093
12	6.286	11.701
13	6.127	11.375
14	5.992	11.098
15	5.875	10.861

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

A probability distribution for which the probability that an observation selected at random from this population falls between a and b $(0 < a < b < \infty)$ is given by the area under the normal distribution between ln(a) and ln(b).

The lognormal distribution is a positively skewed distribution that is simply related to the normal distribution. If something is lognormally distributed, then its logarithm is normally distributed. The natural (base e) logarithm is used.

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

In order to test the goodness-of-fit of the lognormal distribution, take the logarithm of the data and perform the Anderson-Darling test for normality from Section 2.1.7. Using the natural logarithm, replace the linked equation above with linked equation below:

$$z_{(i)} = \frac{\ln\left(x_{(i)}\right) - \bar{x}_L}{s_L}, \quad \text{for } i = 1,\ldots,n$$

Equation 47

where $x_{(i)}$ is the i^{th} smallest sample observation, $\bar{x}_L$ and s_L are the mean and standard deviation of the $\ln(x_i)$ values.

The Anderson-Darling statistic is then computed using the linked equation above and the observed significance level (OSL) is computed using the linked equation above . This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if in fact the data are a sample from a lognormal distribution. If OSL ≤ 0.05, one may conclude (at a five percent risk of being in error) that the population is not lognormally distributed. Otherwise, the hypothesis that the population is lognormally distributed is not rejected. For further information on these procedures, see reference 6.

2.2.2.4.2 Basis value calculations for the Lognormal distribution

If the data set is assumed to be from a population with a lognormal distribution, basis values are calculated using the equation above in section 2.1.3. However, the calculations are performed using the logarithms of the data rather than the original observations. The computed basis values are then transformed back to the original units by applying the inverse of the log transformation.

2.2.3 Non-parametric Basis Values

Non-parametric techniques do not assume any particularly underlying distribution for the population the sample comes from. It does require that the batches be similar enough to be grouped together, so the ADK test must have a positive result. While it can be used instead of assuming the normal, lognormal or Weibull distribution, it typically results in lower basis values. One of following two methods should be used, depending on the sample size.

2.2.3.1 Non-parametric Basis Values for large samples

The required sample sizes for this ranking method differ for A and B basis values. A sample size of at least 29 is needed for the B-basis value while a sample size of 299 is required for the A-basis.

To calculate a B-basis value for n > 28, the value of r is determined with the following formulas:

For B-basis values:

$$r_B = \frac{n}{10} - 1.645\sqrt{\frac{9n}{100}} + 0.23 \qquad \textbf{Equation 48}$$

For A-Basis values:

$$r_A = \frac{n}{100} - 1.645\sqrt{\frac{99n}{10,000}} + 0.29 + \frac{19.1}{n} \qquad \textbf{Equation 49}$$

The formula for the A-basis values should be rounded to the nearest integer. This approximation is exact for most values and for a small percentage of values (less than 0.2%), the approximation errs by one rank on the conservative side.

The B-basis value is the r_B^{th} lowest observation in the data set, while the A-basis values are the r_A^{th} lowest observation in the data set. For example, in a sample of size n = 30, the lowest (r = 1) observation is the B-basis value. Further information on this procedure may be found in reference 7.

2.2.3.2 Non-parametric Basis Values for small samples

The Hanson-Koopmans method (references 8 and 9) is used for obtaining a B-basis value for sample sizes not exceeding 28 and A-basis values for sample sizes less than 299. This procedure requires the assumption that the observations are a random sample from a population for which the logarithm of the cumulative distribution function is concave, an assumption satisfied by a large class of probability distributions. There is substantial empirical evidence that suggests that composite strength data satisfies this assumption.

The Hanson-Koopmans B-basis value is:

$$B = x_{(r)}\left[\frac{x_{(1)}}{x_{(r)}}\right]^k \qquad \text{Equation 50}$$

The A-basis value is:

$$A = x_{(n)}\left[\frac{x_{(1)}}{x_{(n)}}\right]^k \qquad \text{Equation 51}$$

where $x_{(n)}$ is the largest data value, $x_{(1)}$ is the smallest, and $x_{(r)}$ is the r^{th} largest data value. The values of r and k depend on n and are listed in Table 2-3. This method is not used for the B-basis value when $x_{(r)} = x_{(1)}$.

The Hanson-Koopmans method can be used to calculate A-basis values for n less than 299. Find the value k_A corresponding to the sample size n in Table 2-4. For an A-basis value that meets all the requirements of working draft CMH-17 Rev G, there must be at least five batches represented in the data and at least 55 data points. For a B-basis value, there must be at least three batches represented in the data and at least 18 data points.

B-Basis Hanson-Koopmans Table		
n	r	k
2	2	35.177
3	3	7.859
4	4	4.505
5	4	4.101
6	5	3.064
7	5	2.858
8	6	2.382
9	6	2.253
10	6	2.137
11	7	1.897
12	7	1.814
13	7	1.738
14	8	1.599
15	8	1.540
16	8	1.485
17	8	1.434
18	9	1.354
19	9	1.311
20	10	1.253
21	10	1.218
22	10	1.184
23	11	1.143
24	11	1.114
25	11	1.087
26	11	1.060
27	11	1.035
28	12	1.010

Table 2-3: B-Basis Hanson-Koopmans Table

A-Basis Hanson-Koopmans Table					
n	k	n	k	n	k
2	80.00380	38	1.79301	96	1.32324
3	16.91220	39	1.77546	98	1.31553
4	9.49579	40	1.75868	100	1.30806
5	6.89049	41	1.74260	105	1.29036
6	5.57681	42	1.72718	110	1.27392
7	4.78352	43	1.71239	115	1.25859
8	4.25011	44	1.69817	120	1.24425
9	3.86502	45	1.68449	125	1.23080
10	3.57267	46	1.67132	130	1.21814
11	3.34227	47	1.65862	135	1.20620
12	3.15540	48	1.64638	140	1.19491
13	3.00033	49	1.63456	145	1.18421
14	2.86924	50	1.62313	150	1.17406
15	2.75672	52	1.60139	155	1.16440
16	2.65889	54	1.58101	160	1.15519
17	2.57290	56	1.56184	165	1.14640
18	2.49660	58	1.54377	170	1.13801
19	2.42833	60	1.52670	175	1.12997
20	2.36683	62	1.51053	180	1.12226
21	2.31106	64	1.49520	185	1.11486
22	2.26020	66	1.48063	190	1.10776
23	2.21359	68	1.46675	195	1.10092
24	2.17067	70	1.45352	200	1.09434
25	2.13100	72	1.44089	205	1.08799
26	2.09419	74	1.42881	210	1.08187
27	2.05991	76	1.41724	215	1.07595
28	2.02790	78	1.40614	220	1.07024
29	1.99791	80	1.39549	225	1.06471
30	1.96975	82	1.38525	230	1.05935
31	1.94324	84	1.37541	235	1.05417
32	1.91822	86	1.36592	240	1.04914
33	1.89457	88	1.35678	245	1.04426
34	1.87215	90	1.34796	250	1.03952
35	1.85088	92	1.33944	275	1.01773
36	1.83065	94	1.33120	299	1.00000
37	1.81139				

Table 2-4: A-Basis Hanson-Koopmans Table

2.2.4 Analysis of Variance (ANOVA) Basis Values

ANOVA is used to compute basis values when the batch to batch variability of the data does not pass the ADK test. Since ANOVA makes the assumption that the different batches have equal variances, the data is checked to make sure the assumption is valid. Levene's test for equality of variance is used (see section 2.1.8). If the dataset fails Levene's test, the basis values computed are likely to be conservative. Thus this method can still be used but the values produced will be listed as estimates.

2.2.4.1 Calculation of basis values using ANOVA

The following calculations address batch-to-batch variability. In other words, the only grouping is due to batches and the k-sample Anderson-Darling test (Section 2.1.6) indicates that the batch to batch variability is too large to pool the data. The method is based on the one-way analysis of variance random-effects model, and the procedure is documented in reference 10.

ANOVA separates the total variation (called the sum of squares) of the data into two sources: between batch variation and within batch variation.

First, statistics are computed for each batch, which are indicated with a subscript $\left(n_i, \bar{x}_i, s_i^2\right)$ while statistics that were computed with the entire dataset do not have a subscript. Individual data values are represented with a double subscript, the first number indicated the batch and the second distinguishing between the individual data values within the batch. k stands for the number of batches in the analysis. With these statistics, the Sum of Squares Between batches (SSB) and the Total Sum of Squares (SST) are computed:

$$SSB = \sum_{i=1}^{k} n_i \bar{x}_I^2 - n\bar{x}^2 \quad \textbf{Equation 52}$$

$$SST = \sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}^2 - n\bar{x}^2 \quad \textbf{Equation 53}$$

The within-batch, or error, sum of squares (SSE) is computed by subtraction

$$SSE = SST - SSB \quad \textbf{Equation 54}$$

Next, the mean sums of squares are computed:

$$MSB = \frac{SSB}{k-1} \quad \textbf{Equation 55}$$

$$MSE = \frac{SSE}{n-k} \quad \textbf{Equation 56}$$

Since the batches need not have equal numbers of specimens, an 'effective batch size,' is defined as

$$n' = \frac{n - \frac{1}{n}\sum_{i=1}^{k} n_i^2}{k-1} \quad \textbf{Equation 57}$$

Using the two mean squares and the effective batch size, an estimate of the population standard deviation is computed:

$$S = \sqrt{\frac{MSB}{n'} + \left(\frac{n'-1}{n'}\right)MSE} \quad \textbf{Equation 58}$$

Two k-factors are computed using the methodology of section 2.2.2 using a sample size of n (denoted k_0) and a sample size of k (denoted k_1). Whether this value is an A- or B-basis value depends only on whether k_0 and k_1 are computed for A or B-basis values.

Denote the ratio of mean squares by

$$u = \frac{MSB}{MSE}$$ **Equation 59**

If u is less than one, it is set equal to one. The tolerance limit factor is

$$T = \frac{k_0 - \frac{k_1}{\sqrt{n'}} + \left(k_1 - k_0\right)\sqrt{\frac{u}{u+n'-1}}}{1 - \frac{1}{\sqrt{n'}}}$$ **Equation 60**

The basis value is $\bar{x} - TS$.

The ANOVA method can produce extremely conservative basis values when a small number of batches are available. Therefore, when less than five (5) batches are available and the ANOVA method is used, the basis values produced will be listed as estimates.

2.3 Single Batch and Two Batch Estimates using Modified CV

This method has not been approved for use by the CMH-17 organization. Values computed in this manner are estimates only. It is used only when fewer than three batchs are available and no valid B-basis value could be computed using any other method. The estimate is made using the mean of the data and setting the coefficient of variation to 8 percent if it was less than that. A modified standard deviation (S_{adj}) was computed by multiplying the mean by 0.08 and computing the A and B-basis values using this inflated value for the standard deviation.

Estimated B-Basis = $\bar{X} - k_b S_{adj} = \bar{X} - k_b \cdot 0.08 \cdot \bar{X}$ **Equation 61**

2.4 Lamina Variability Method (LVM)

This method has not been approved for use by the CMH-17 organization. Values computed in this manner are estimates only. It is used only when the sample size is less than 16 and no valid B-basis value could be computed using any other method. The prime assumption for applying the LVM is that the intrinsic strength variability of the laminate (small) dataset is no greater than the strength variability of the lamina (large) dataset. This assumption was tested and found to be reasonable for composite materials as documented by Tomblin and Seneviratne [12].

To compute the estimate, the coefficients of variation (CVs) of laminate data are paired with lamina CV's for the same loading condition and environmental condition. For example, the 0º compression lamina CV CTD condition is used with open hole compression CTD condition. Bearing and in-plane shear laminate CV's are paired with 0º compression lamina CV's. However, if the laminate CV is larger than the corresponding lamina CV, the larger laminate CV value is used.

The LVM B-basis value is then computed as:

LVM Estimated B-Basis = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot \max\left(CV_1, CV_2\right)$ **Equation 62**

When used in conjunction with the modified CV approach, a minimum value of 8% is used for the CV.

Mod CV LVM Estimated B-Basis = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot Max\left(8\%, CV_1, CV_2\right)$ **Equation 63**

With:

$\bar{X}_1$ the mean of the laminate (small dataset)

N_1 the sample size of the laminate (small dataset)

N_2 the sample size of the lamina (large dataset)

CV_1 is the coefficient of variation of the laminate (small dataset)

CV_2 is the coefficient of variation of the lamina (large dataset)

$K_{(N_1,N_2)}$ is given in Table 2-5

		N1													
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
N1+N2-2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	4.508	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	3.827	3.607	0	0	0	0	0	0	0	0	0	0	0	0
	5	3.481	3.263	3.141	0	0	0	0	0	0	0	0	0	0	0
	6	3.273	3.056	2.934	2.854	0	0	0	0	0	0	0	0	0	0
	7	3.134	2.918	2.796	2.715	2.658	0	0	0	0	0	0	0	0	0
	8	3.035	2.820	2.697	2.616	2.558	2.515	0	0	0	0	0	0	0	0
	9	2.960	2.746	2.623	2.541	2.483	2.440	2.405	0	0	0	0	0	0	0
	10	2.903	2.688	2.565	2.484	2.425	2.381	2.346	2.318	0	0	0	0	0	0
	11	2.856	2.643	2.519	2.437	2.378	2.334	2.299	2.270	2.247	0	0	0	0	0
	12	2.819	2.605	2.481	2.399	2.340	2.295	2.260	2.231	2.207	2.187	0	0	0	0
	13	2.787	2.574	2.450	2.367	2.308	2.263	2.227	2.198	2.174	2.154	2.137	0	0	0
	14	2.761	2.547	2.423	2.341	2.281	2.236	2.200	2.171	2.147	2.126	2.109	2.093	0	0
	15	2.738	2.525	2.401	2.318	2.258	2.212	2.176	2.147	2.123	2.102	2.084	2.069	2.056	0
	16	2.719	2.505	2.381	2.298	2.238	2.192	2.156	2.126	2.102	2.081	2.063	2.048	2.034	2.022
	17	2.701	2.488	2.364	2.280	2.220	2.174	2.138	2.108	2.083	2.062	2.045	2.029	2.015	2.003
	18	2.686	2.473	2.348	2.265	2.204	2.158	2.122	2.092	2.067	2.046	2.028	2.012	1.999	1.986
	19	2.673	2.459	2.335	2.251	2.191	2.144	2.108	2.078	2.053	2.032	2.013	1.998	1.984	1.971
	20	2.661	2.447	2.323	2.239	2.178	2.132	2.095	2.065	2.040	2.019	2.000	1.984	1.970	1.958
	21	2.650	2.437	2.312	2.228	2.167	2.121	2.084	2.053	2.028	2.007	1.988	1.972	1.958	1.946
	22	2.640	2.427	2.302	2.218	2.157	2.110	2.073	2.043	2.018	1.996	1.978	1.962	1.947	1.935
	23	2.631	2.418	2.293	2.209	2.148	2.101	2.064	2.033	2.008	1.987	1.968	1.952	1.938	1.925
	24	2.623	2.410	2.285	2.201	2.139	2.092	2.055	2.025	1.999	1.978	1.959	1.943	1.928	1.916
	25	2.616	2.402	2.277	2.193	2.132	2.085	2.047	2.017	1.991	1.969	1.951	1.934	1.920	1.907
	26	2.609	2.396	2.270	2.186	2.125	2.078	2.040	2.009	1.984	1.962	1.943	1.927	1.912	1.900
	27	2.602	2.389	2.264	2.180	2.118	2.071	2.033	2.003	1.977	1.955	1.936	1.920	1.905	1.892
	28	2.597	2.383	2.258	2.174	2.112	2.065	2.027	1.996	1.971	1.949	1.930	1.913	1.899	1.886
	29	2.591	2.378	2.252	2.168	2.106	2.059	2.021	1.990	1.965	1.943	1.924	1.907	1.893	1.880
	30	2.586	2.373	2.247	2.163	2.101	2.054	2.016	1.985	1.959	1.937	1.918	1.901	1.887	1.874
	40	2.550	2.337	2.211	2.126	2.063	2.015	1.977	1.946	1.919	1.897	1.877	1.860	1.845	1.832
	50	2.528	2.315	2.189	2.104	2.041	1.993	1.954	1.922	1.896	1.873	1.853	1.836	1.820	1.807
	60	2.514	2.301	2.175	2.089	2.026	1.978	1.939	1.907	1.880	1.857	1.837	1.819	1.804	1.790
	70	2.504	2.291	2.164	2.079	2.016	1.967	1.928	1.896	1.869	1.846	1.825	1.808	1.792	1.778
	80	2.496	2.283	2.157	2.071	2.008	1.959	1.920	1.887	1.860	1.837	1.817	1.799	1.783	1.769
	90	2.491	2.277	2.151	2.065	2.002	1.953	1.913	1.881	1.854	1.830	1.810	1.792	1.776	1.762
	100	2.486	2.273	2.146	2.060	1.997	1.948	1.908	1.876	1.849	1.825	1.805	1.787	1.771	1.757
	125	2.478	2.264	2.138	2.051	1.988	1.939	1.899	1.867	1.839	1.816	1.795	1.777	1.761	1.747
	150	2.472	2.259	2.132	2.046	1.982	1.933	1.893	1.861	1.833	1.809	1.789	1.770	1.754	1.740
	175	2.468	2.255	2.128	2.042	1.978	1.929	1.889	1.856	1.828	1.805	1.784	1.766	1.750	1.735
	200	2.465	2.252	2.125	2.039	1.975	1.925	1.886	1.853	1.825	1.801	1.781	1.762	1.746	1.732

Table 2-5: B-Basis factors for small datasets using variability of corresponding large dataset

2.5 0º Lamina Strength Derivation

Lamina strength values in the 0º direction were not obtained directly for any conditions during compression tests. They are derived from the cross-ply lamina test results using a back out formula. Unless stated otherwise, the 0° lamina strength values were derived using the following formula:

$F_{0^\circ}^{u} = F_{0^\circ/90^\circ}^{u} \cdot BF$ where BF is the backout factor.

$F_{0^\circ/90^\circ}^{u}$ =UNC0 or UNT0 strength values

$$BF = \frac{E_1\left[V_0E_2 + \left(1-V_0\right)E_1\right] - \left(\nu_{12}E_2\right)^2}{\left[V_0E_1 + \left(1-V_0\right)E_2\right]\left[V_0E_2 + \left(1-V_0\right)E_1\right] - \left(\nu_{12}E_2\right)^2}$$ **Equation 64**

V_0=fraction of 0º plies in the cross-ply laminate (½ for UNT0 and 1/3 for UNC0)

E_1 = Average across of batches of modulus for LC and LT as appropriate

E_2 = Average across of batches of modulus for TC and TT as appropriate

ν_{12} = major Poisson's ratio of 0º plies from an average of all batches

This formula can also be found in section 2.4.2, equation 2.4.2.1(b) of working draft CMH-17 Rev G.

In computing these strength values, the values for each environment are computed separately. The compression values are computed using only compression data, the tension values are computed using only tension data. Both normalized and as-measured computations are done using the as-measured and normalized strength values from the UNC0 and UNT0 strength values.

2.5.1 0º Lamina Strength Derivation (Alternate Formula)

In some cases, the previous formula cannot be used. For example, if there were no ETD tests run for transverse tension and compression, the value for E_2 would not be available. In that case, this alternative formula is used to compute the strength values for longitudinal tension and compression. It is similar to, but not quite the same as the formula detailed above. It requires the UNC0 and UNT0 strength and modulus data in addition to the LC and LT modulus data.

The 0° lamina strength values for the LC ETD condition were derived using the formula:

$$F_{0^\circ}^{cu} = F_{0^\circ/90^\circ}^{cu}\frac{E_1^c}{E_{0^\circ/90^\circ}^c}, \quad F_{0^\circ}^{tu} = F_{0^\circ/90^\circ}^{tu}\frac{E_1^t}{E_{0^\circ/90^\circ}^t}$$ **Equation 65**

with $F_{0^\circ}^{cu}$, $F_{0^\circ}^{tu}$ the derived mean lamina strength value for compression and tension respectively

$F_{0^\circ/90^\circ}^{cu}$, $F_{0^\circ/90^\circ}^{tu}$ are the mean strength values for UNC0 and UNT0 respectively

E_1^c, E_1^t are the modulus values for LC and LT respectively

$E_{0^\circ/90^\circ}^c$, $E_{0^\circ/90^\circ}^t$ are the modulus values for UNC0 and UNT0 respectively

This formula can also be found in section 2.4.2, equation 2.4.2.1(d) of working draft CMH-17 Rev G.

3. Summary of Results

The basis values for all tests are summarized in the following tables. The NCAMP recommended B-basis values meet all requirements of working draft CMH-17 Rev G. However, not all test data meets those requirements. The summary tables provide a complete listing of all computed basis values and estimates of basis values. Data that does not meet the requirements of working draft CMH-17 Rev G are shown in shaded boxes and labeled as estimates. Basis values computed with the modified coefficient of variation (CV) are presented whenever possible. Basis values and estimates computed without that modification are presented for all tests.

3.1 NCAMP Recommended B-basis Values

The following rules are used in determining what B-basis value, if any, is included in tables Table 3-1and Table 3-2 of recommended values.

1. Recommended values are NEVER estimates. Only B-basis values that meet all requirements of working draft CMH-17 Rev G are recommended.
2. Modified CV basis values are preferred. Recommended values will be the modified CV basis value when available. The CV provided with the recommended basis value will be the one used in the computation of the basis value.
3. Only normalized basis values are given for properties that are normalized.
4. ANOVA B-basis values are not recommended since only three batches of material are available and working draft CMH-17 Rev G recommends that no less than five batches be used when computing basis values with the ANOVA method.
5. Basis values of 90% or more of the mean value imply that the CV is unusually low and may not be conservative.Caution is recommended with B-Basis values calculated from STAT17 when the B-basis value is 90% or more of the average value. Such values will be indicated.
6. If the data appear questionable (e.g. when the CTD-RTD-ETW trend of the basis values are not consistent with the CTD-RTD-ETW trend of the average values), then the B-basis values will not be recommended.

NCAMP Recommended B-basis Values for
Cytec 5215 T40-800 Unitape

All B-basis values in this table meet the standards for publication in CMH-17G Handbook
Values are for normalized data unless otherwise noted

Lamina Strength Tests

Environment	Statistic	LT from UNT0	LT	LC from UNC0	TT	TC	SBS*	IPS* 0.2% Offset	IPS* Peak before 5% Strain	IPS* 5% Strain	UNT0	UNC0
CTD (-65° F)	B-basis	288.862	330.276	187.746	5.342	34.459	12.814	8.197**	11.231		153.062	71.704
	Mean	326.207	369.505	214.727	6.308	40.102	14.071	8.512	12.680		172.776	81.834
	CV	6.442	6.821	10.476	8.039	7.384	6.255	2.656	6.000		6.442	10.476
RTD (70° F)	B-basis	318.483	332.422	176.749	4.706	27.065	10.036	5.304			167.488	66.752
	Mean	355.978	371.255	203.730	6.087	29.672	11.293	5.989			187.281	76.882
	CV	6.000	6.083	6.788	12.583	6.000	6.210	6.000			6.000	6.788
ETD (180° F)	B-basis			153.315			8.154					54.721
	Mean			180.425			9.410					64.899
	CV			7.579			6.000					7.579
ETW (180° F)	B-basis	NA:A	316.079	114.560	3.057	15.288	6.570	3.351		5.464	NA:A	42.363
	Mean	296.131	355.459	141.541	3.469	17.895	7.418	3.783		6.169	154.598	52.493
	CV	4.805	6.056	7.454	6.412	6.000	6.000	6.000		6.000	4.805	7.454

Notes: The modified CV B-basis value is recommended when available.
The CV provided corresponds with the B-basis value given.
NA implies that tests were run but data did not meet NCAMP recommended requirements.
"NA: A" indicates ANOVA with 3 batches, "NA: I" indicates insufficient data,
Shaded empty boxes indicate that no test data is available for that property and condition.
* Data is as-measured rather than normalized
** indicates the Stat17 B-basis value is greater than 90% of the mean value.

Table 3-1 : NCAMP recommended B-basis values for lamina test data

NCAMP Recommended B-basis Values for
Cytec 5215 T40-800 Unitape

All B-basis values in this table meet the standards for publication in CMH-17G Handbook
Values are for normalized data unless otherwise noted

Laminate Strength Tests

Lay-up	ENV	Statistic	OHT	OHC	FHT	FHC	UNT	UNC	SSB 2% Offset	SSB Ultimate	SBS1*
25/50/25	CTD (-65º F)	B-basis	57.051		62.265		92.790				
		Mean	64.033		69.566		103.866				
		CV	6.241		6.000		6.000				
	RTD (70º F)	B-basis	58.436	37.549	61.207	56.969	93.171	71.194	93.777	112.632	7.907
		Mean	65.418	42.396	68.508	63.033	104.246	78.737	104.483	127.172	8.802
		CV	6.226	6.000	6.000	6.000	6.000	6.059	6.339	6.000	6.662
	ETW (180º F)	B-basis	60.373	29.400	60.501	41.132	100.908	53.530	79.098	89.991	5.920
		Mean	67.354	33.195	67.802	47.196	111.984	61.072	89.804	102.642	6.819
		CV	6.004	6.000	6.458	6.386	6.000	6.000	6.000	6.468	6.000
10/80/10	CTD (-65º F)	B-basis	39.961		48.787		60.826				
		Mean	44.348		53.095		67.324				
		CV	6.000		5.679		6.000				
	RTD (70º F)	B-basis	38.304	33.427	43.955	43.164	57.054	53.175	92.562	120.920	
		Mean	42.691	36.919	48.911	47.656	63.552	58.951	103.553	136.531	
		CV	6.000	6.000	6.000	6.000	6.000	6.110	6.630	6.000	
	ETW (180º F)	B-basis	35.306	24.643	39.172	31.476	50.056	35.335	78.189	102.813	
		Mean	39.693	28.135	44.128	35.968	56.554	41.111	89.179	108.136	
		CV	6.000	6.000	6.000	6.000	6.000	6.985	6.111	3.522	
50/40/10	CTD (-65º F)	B-basis	NA: A		86.417		166.040				
		Mean	102.201		97.573		184.761				
		CV	9.248		6.000		6.000				
	RTD (70º F)	B-basis	NA: A	49.837	NA: A	65.817	166.626	100.058	94.645	115.331	
		Mean	120.850	55.091	98.661	72.654	185.266	110.304	105.471	127.773	
		CV	10.468	6.000	4.050	6.000	6.000	6.000	6.453	6.000	
	ETW (180º F)	B-basis	NA: A	37.666	86.957	47.741	152.494	72.259	77.989	93.039	
		Mean	133.411	42.920	98.873	54.577	171.214	82.299	88.899	105.578	
		CV	8.186	6.000	6.325	6.000	6.000	6.000	6.069	6.073	

Notes: The modified CV B-basis value is recommended when available.
The CV provided corresponds with the B-basis value given.
NA implies that tests were run but data did not meet NCAMP recommended requirements.
"NA: A" indicates ANOVA with 3 batches, "NA: I" indicates insufficient data,
Shaded empty boxes indicate that no test data is available for that property and condition.
* Data is as-measured rather than normalized
** indicates the Stat17 B-basis value is greater than 90% of the mean value.

Table 3-2 : NCAMP Recommended B-basis values for laminate test data

3.2 Lamina and Laminate Summary Tables

Prepreg Material: Cytec CYCOM® 5215 T40-800 Unitape NMS 323/1 Material Specification		**Cytec CYCOM® 5215 T40-800 Unitape Lamina Properties Summary**
Fiber: Cytec T40-800	**Resin:** CYCOM® 5215	
Tg(dry): 340.21°F	**Tg(wet):** 263.75°F	**Tg METHOD:** DMA (SRM 18R-94)
PROCESSING: NPS 81323 Baseline "C" Cure Cycle		

Date of fiber manufacture	11/14/2005 to 6/28/2006	**Date of testing**	4/8/2010 to 11/9/2010
Date of resin manufacture	12/2006 to 1/2007	**Date of data submittal**	2/1/2011
Date of prepreg manufacture	12/2006 to 1/2007	**Date of analysis**	4/24/2012 to 5/30/2012
Date of composite manufacture	Feb-09		

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported: As-measured followed by normalized values in parentheses, normalizing tply: 0.0057 in

Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only

These values may not be used for certification unless specifically allowed by the certifying agency

	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
F_1^{tu} (ksi)	266.455	293.335	328.622	292.645	323.217	358.655				231.426	262.774	298.212
from UNT0*	(246.703)	(288.862)	(326.207)	(278.409)	(318.483)	(355.978)				(221.484)	(260.001)	(296.131)
F_1^{tu} (ksi)	332.508	333.405	372.626	353.727	336.257	375.082				293.441	317.941	357.312
from LT	(338.058)	(330.276)	(369.505)	(340.106)	(332.422)	(371.255)				(302.937)	(316.079)	(355.459)
E_1^t			21.531			21.816						21.111
(Msi)			(21.352)			(21.583)						(20.993)
ν_{12}^t			0.333			0.164						0.342
F_2^{tu} (ksi)	5.342	NA	6.308	4.706	NA	6.087				3.159	3.057	3.469
E_2^t (Msi)			1.281			1.130						0.935
F_1^{cu} (ksi)	190.463	189.222	217.099	179.774	178.532	206.409	156.590	155.343	183.353	116.133	114.891	142.768
from UNC0*	(189.108)	(187.746)	(214.727)	(178.112)	(176.749)	(203.730)	(154.685)	(153.315)	(180.425)	(115.922)	(114.560)	(141.541)
E_1^c			19.143			18.947			19.343			18.922
(Msi)			(18.852)			(18.669)			(19.038)			(18.717)
ν_{12}^c			0.306			0.366			0.375			0.362
F_2^{cu} (ksi)	34.932	34.459	40.102	28.243	27.065	29.672				16.465	15.288	17.895
E_2^c (Msi)			1.363			1.248						1.065
ν_{21}^c			0.030			0.025						0.019
$F_{12}^{s\,max}$ (ksi)	9.962	11.231	12.680	NA	NA	NA				NA	NA	NA
$F_{12}^{s5\%}$ (ksi)	NA	NA	NA	9.930	NA	10.325				5.582	5.464	6.169
$F_{12}^{s0.2\%}$ (ksi)	8.197	NA	8.512	5.576	5.304	5.989				3.638	3.351	3.783
G_{12}^s (Msi)			0.673			0.542						0.403
SBS (ksi)	10.474	12.814	14.071	9.004	10.036	11.293	8.134	8.154	9.410	5.691	6.570	7.418
UNT0	141.064	155.414	173.974	153.882	169.949	188.590				120.791	137.007	155.648
(ksi)	(130.666)	(153.062)	(172.776)	(146.474)	167.488	(187.281)				(115.630)	NA	(154.598)
			11.237			11.230						11.256
(Msi)			(11.158)			(11.150)						(11.178)
UNC0	71.559	72.140	82.581	66.739	67.320	77.761	54.386	54.969	65.460	45.440	42.449	52.891
(ksi)	(72.208)	(71.704)	(81.834)	(67.257)	(66.752)	(76.882)	(55.227)	(54.721)	(64.899)	(42.867)	(42.363)	(52.493)
			7.083			7.324			6.906			7.459
(Msi)			(7.021)			(7.241)			(6.848)			(7.381)
ν of UNC0			0.037			0.033			0.027			0.031

***** *Derived from cross-ply using back-out factor*

Table 3-3: Summary of Test Results for Lamina Data

Prepreg Material:	Cytec CYCOM® 5215 T40-800 Unitape NMS 323/1 Material Specification		**Cytec CYCOM® 5215 T40-800 Unitape Laminate Properties Summary**
Fiber:	Cytec T40-800	**Resin:** CYCOM® 5215	
Tg(dry): 340.21°F	**Tg(wet):** 263.75°F	**Tg METHOD :** DMA (SRM 18R-94)	
PROCESSING:	NPS 81323 Baseline "C" Cure Cycle		

Date of fiber manufacture	11/14/2005 to 6/28/2006	**Date of testing**	4/8/2010 to 11/9/2010
Date of resin manufacture	12/2006 to 1/2007	**Date of data submittal**	2/1/2011
Date of prepreg manufacture	12/2006 to 1/2007	**Date of analysis**	4/24/2012 to 5/30/2012
Date of composite manufacture	Feb-09		

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported as normalized used a normalizing t_{ply} of 0.0057 in

Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only

These values may not be used for certification unless specifically allowed by the certifying agency

Test	Property	Layup:		Quasi Isotropic 25/50/25			"Soft" 10/80/10			"Hard" 50/40/10		
		Test Condition	Unit	B-value	Mod. CV B-value	Mean	B-value	Mod. CV B-value	Mean	B-value	Mod. CV B-value	Mean
OHT (normalized)	Strength	CTD	ksi	50.211	57.051	64.033	43.091	39.961	44.348	58.476	NA	102.201
		RTD	ksi	49.988	58.436	65.418	41.434	38.304	42.691	58.581	NA	120.850
		ETW	ksi	53.272	60.373	67.354	38.437	35.306	39.693	62.966	NA	133.411
OHC (normalized)	Strength	RTD	ksi	39.489	37.549	42.396	35.680	33.427	36.919	52.048	49.837	55.091
		ETW	ksi	31.994	29.400	33.195	26.896	24.643	28.135	39.877	37.666	42.920
UNT (normalized)	Strength	CTD	ksi	98.248	92.790	103.866	64.487	60.826	67.324	176.974	166.040	184.761
	Modulus		Msi	---	---	7.948	---	---	4.948	---	---	12.334
	Strength	RTD	ksi	98.628	93.171	104.246	60.715	57.054	63.552	156.415	166.626	185.266
	Modulus		Msi	---	---	7.691	---	---	4.721	---	---	12.367
	Strength	ETW	ksi	106.366	100.908	111.984	48.568	50.056	56.554	142.971	152.494	171.214
	Modulus		Msi	---	---	7.599	---	---	4.331	---	---	11.908
UNC (normalized)	Strength	RTD	ksi	73.874	71.194	78.737	47.636	53.175	58.951	104.612	100.058	110.304
	Modulus		Msi	---	---	7.177	---	---	4.553	---	---	11.352
	Strength	ETW	ksi	56.209	53.530	61.072	36.435	35.335	41.111	76.722	72.259	82.299
	Modulus		Msi	---	---	6.732	---	---	3.835	---	---	10.748
FHT (normalized)	Strength	CTD	ksi	65.171	62.265	69.566	48.787	NA	53.095	79.623	86.417	97.573
		RTD	ksi	53.987	61.207	68.508	44.387	43.955	48.911	72.922	87.334	98.661
		ETW	ksi	47.602	60.501	67.802	41.211	39.172	44.128	70.806	86.957	98.873
FHC (normalized)	Strength	RTD	ksi	60.005	56.969	63.033	45.912	43.164	47.656	69.379	65.817	72.654
		ETW	ksi	38.272	41.132	47.196	34.225	31.476	35.968	51.302	47.741	54.577
Single Shear Bearing (normalized)	2% Offset Strength	RTD	ksi	96.884	93.777	104.483	95.251	92.562	103.553	97.539	94.645	105.471
		ETW	ksi	82.204	79.098	89.804	80.878	78.189	89.179	80.905	77.989	88.899
	Ultimate Strength	RTD	ksi	106.814	112.632	127.172	130.548	120.920	136.531	120.101	115.331	127.773
		ETW	ksi	80.598	89.991	102.642	102.813	NA	108.136	97.846	93.039	105.578
SBS1 (as-measured)	Strength	RTD	ksi	7.918	7.907	8.802	---	---	---	---	---	---
		ETW	ksi	5.956	5.920	6.819	---	---	---	---	---	---
CAI (Normalized)	Strength	RTD	ksi	---	---	16.718	---	---	---	---	---	---

Table 3-4: Summary of Test Results for Laminate Data

4. Test Results, Statistics, Basis Values and Graphs

Test data for fiber dominated properties was normalized according to nominal cured ply thickness. Both normalized and as-measured statistics were included in the tables, but only the normalized data values were graphed. Test failures, outliers and explanations regarding computational choices were noted in the accompanying text for each test.

All individual specimen results are graphed for each test by batch and environmental condition with a line indicating the recommended basis values for each environmental condition. The data is jittered (moved slightly to the left or right) in order for all specimen values to be clearly visible. The strength values are always graphed on the vertical axis with the scale adjusted to include all data values and their corresponding basis values. The vertical axis may not include zero. The horizontal axis values will vary depending on the data and how much overlapping there was of the data within and between batches. When there was little variation, the batches were graphed from left to right. The environmental conditions were identified by the shape and color of the symbol used to plot the data. Otherwise, the environmental conditions were graphed from left to right and the batches were identified by the shape and color of the symbol.

When a dataset fails the Anderson-Darling k-sample (ADK) test for batch-to-batch variation, an ANOVA analysis is required. In order for B-basis values computed using the ANOVA method, data from five batches are required. Since this qualification dataset has only three batches, the basis values computed using ANOVA are considered estimates only. However, the basis values resulting from the ANOVA method using only three batches may be overly conservative. The ADK test is performed again after a transformation of the data according to the assumptions of the modified CV method (see section 2.1.4 for details). If the dataset still passes the ADK test at this point, modified CV basis values are provided. If the dataset does not pass the ADK test after the transformation, estimates may be computed using the modified CV method per the guidelines in CMH-17 Vol 1 Chapter 8 section 8.3.10.

4.1 Longitudinal (0º) Tension (LT)

The Longitudinal Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The Longitudinal Tension strengths are computed two different ways; directly from LT specimens and indirectly (derived) from UNT0 specimens via the formulas specified in section 2.5. The derived values for the CTD, RTD and ETW conditions were computed using equation 64 in that section. The results of both the values measured directly from the LT specimens and the values computed from the UNT0 specimens are presented here.

The datasets for LT strength derived from the UNT0 datasets all fail the ADK test for batch-to-batch variability, so pooling was not appropriate and the single point ANOVA method was used. All three of the as-measured datasets (CTD, RTD & ETW) as well as the normalized CTD and RTD datasets passed the ADK test after applying the modified CV transform to the data, so pooling was appropriate for the modified CV basis values with the exception of the normalized ETW dataset. A- and B-estimates made using the modified CV method are provided for the normalized ETW dataset, but they are considered estimates only due to the failure of the ADK test.

There was one outlier, it was the lowest value in batch one of the ETW dataset. It was an outlier for both the normalized and as-measured datasets. It was an outlier only for both batch one and not for the ETW condition. It was retained for this analysis.

Statistics, basis values and estimates are given for strength data in Table 4-1 and for the modulus data in Table 4-2. The data and the B-basis values are shown graphically in Figure 4-1.

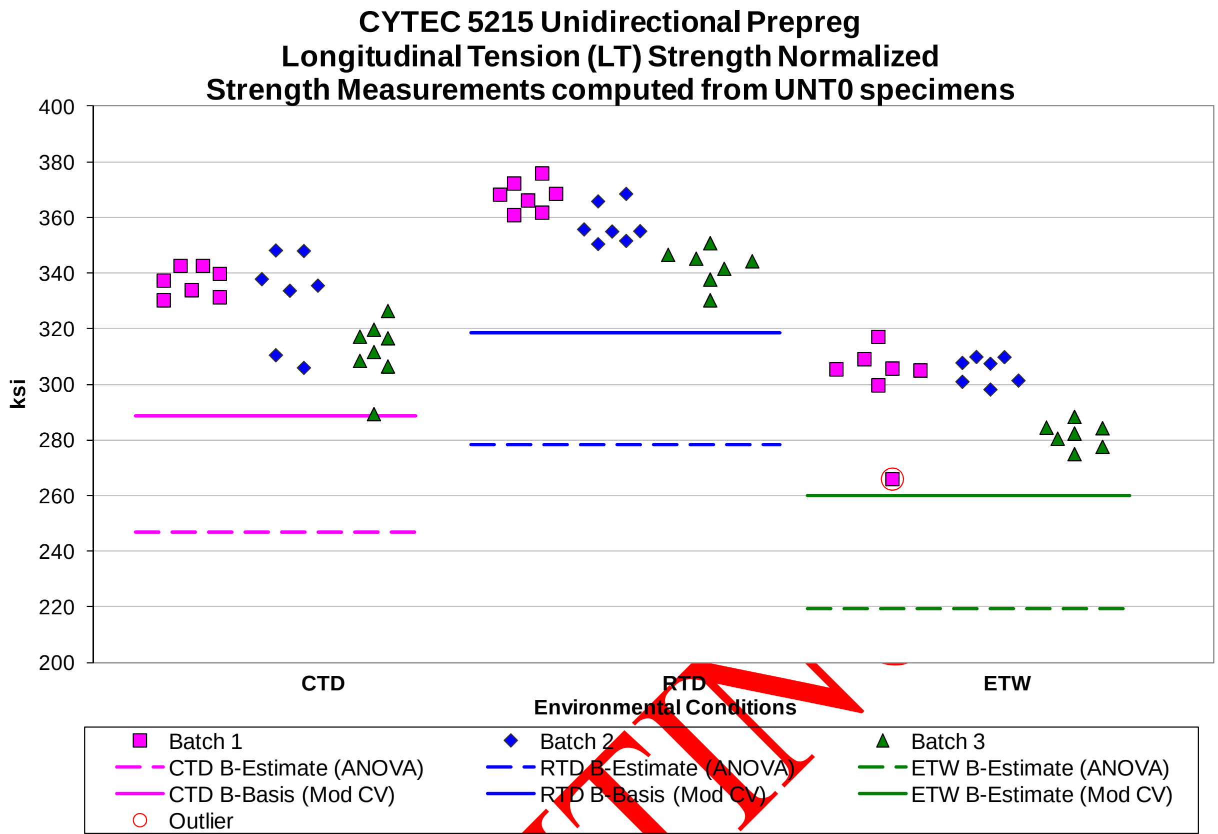

Figure 4-1 Batch plot for LT strength from UNT0 normalized

Longitudinal Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	326.207	355.978	296.131	328.622	358.655	298.212
Stdev	15.932	12.255	14.229	15.392	11.247	14.317
CV	4.884	3.443	4.805	4.684	3.136	4.801
Mod CV	6.442	6.000	6.402	6.342	6.000	6.400
Min	289.484	330.411	266.106	293.987	333.840	265.974
Max	348.323	376.017	317.233	354.688	376.400	321.777
No. Batches	3	3	3	3	3	3
No. Spec.	22	21	21	22	21	21
Basis Values and Estimates						
B-estimate	246.703	278.409	221.484	266.455	292.645	231.426
A-Estimate	189.934	223.030	168.199	222.063	245.521	183.755
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	288.862	318.483		293.335	323.217	262.774
B-Estimate			260.001			
A-estimate	263.072	292.727	234.265	269.384	299.294	238.850
Method	pooled	pooled	normal	pooled	pooled	pooled

Table 4-1: Statistics and Basis values for LT strength from UNT0

Longitudinal Tension Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	21.352	21.583	20.993	21.531	21.816	21.111
Stdev	0.767	0.399	0.446	0.711	0.534	0.503
CV	3.590	1.850	2.127	3.304	2.447	2.382
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	20.049	20.943	20.200	19.812	20.763	20.394
Max	22.926	22.372	22.131	22.555	22.722	22.060
No. Batches	3	3	3	3	3	3
No. Spec.	24	27	21	24	27	21

Table 4-2: Statistics from LT modulus

For completeness and for comparison purposes, the LT strength values are given in Table 4-3. The data and the B-basis values are shown graphically in Figure 4-2. Neither the normalized nor the as-measured ETW datasets passed the ADK test, the single point ANOVA method was used. The normalized CTD and RTD data could be pooled. The as-measured CTD data did not fit a normal distribution, the Weibull distribution was the best choice for the single-point analysis. After applying the modified CV transformation to the data, the normalized and as-measured ETW datasets passed the ADK test. All three conditions could be pooled to compute modified CV basis values for both the normalized and as-measured datasets.

There were two outliers in the LT strength values. The lowest value in batch one of the CTD condition was an outlier for both the normalized and as-measured datasets. In the as-measured dataset, it was an outlier for both batch one and for the CTD condition but for the normalized dataset, it was an outlier only for the CTD condition and not for batch one. The highest value in batch two of the ETW condition was an outlier for both the normalized and as-measured datasets. It was an outlier for batch two but not the ETW condition. Both outliers were retained for this analysis.

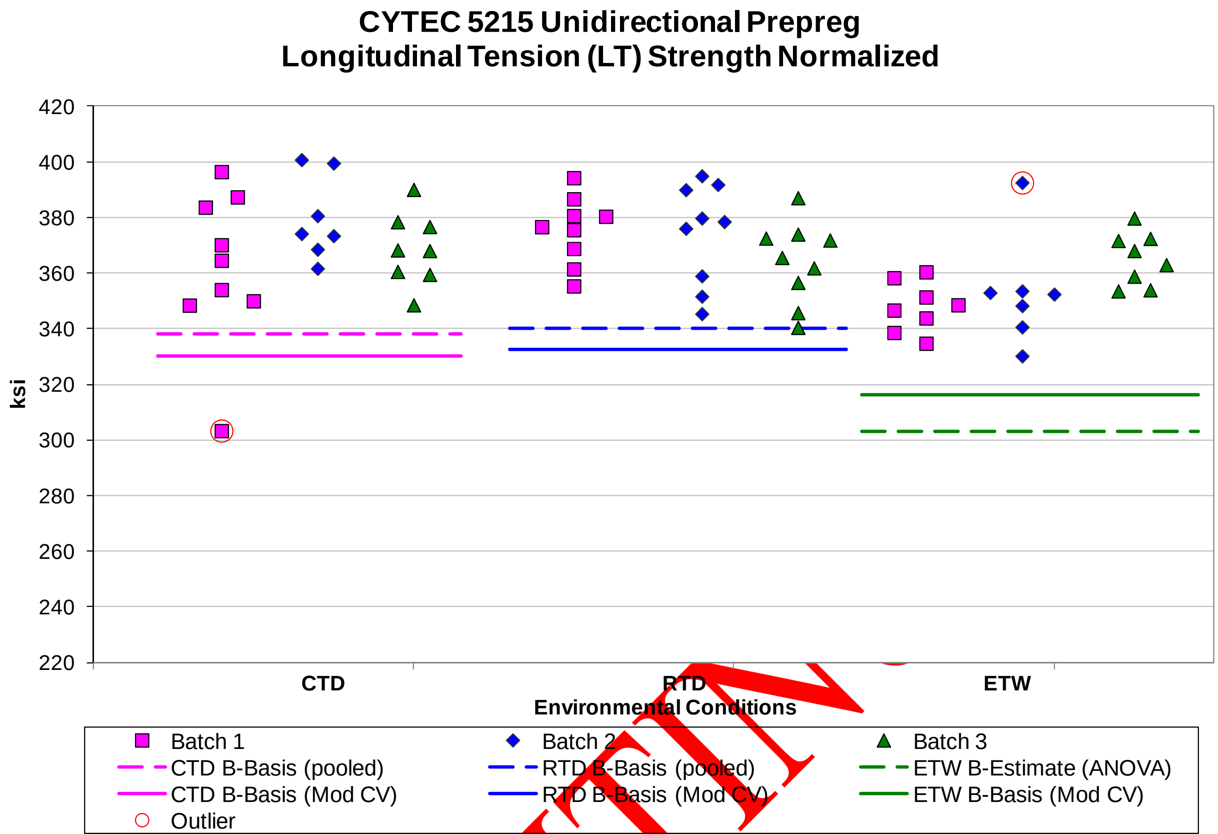

Figure 4-2 Batch plot for LT strength normalized

Longitudinal Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Mean	369.505	371.255	355.459	372.626	375.082	357.312
Stdev	20.845	15.468	14.616	20.444	11.795	14.812
CV	5.641	4.167	4.112	5.486	3.145	4.145
Mod CV	6.821	6.083	6.056	6.743	6.000	6.073
Min	303.380	340.515	330.258	299.116	351.831	331.713
Max	400.818	394.996	392.598	404.031	400.906	388.059
No. Batches	3	3	3	3	3	3
No. Spec.	24	27	23	24	27	23
Basis Values and Estimates						
B-basis Value	338.058	340.106		332.508	353.727	
B-Estimate			302.937			293.441
A-Estimate	316.302	318.283	265.408	291.327	338.342	247.814
Method	pooled	pooled	ANOVA	Weibull	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	330.276	332.422	316.079	333.405	336.257	317.941
A-estimate	303.539	305.611	289.370	306.675	309.452	291.238
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-3: Statistics and Basis values for LT strength

4.2 Transverse (90º) Tension (TT)

Transverse Tension data is not normalized for unidirectional tape. The three environments could not be pooled due to the failure of Levene's test for equality. No modified CV basis values are provided for the CTD and RTD environments due to the as-measured coefficient of variation being above 8% for both of those environments. The Weibull distribution was used to compute the basis values for the RTD condition because the Weibull distribution provided a much better fit (p = 0.060) for the RTD data as opposed to the normal distribution (p=0.0534).

There was one outlier. The lowest value in batch one of the RTD condition was an outlier for the RTD condition, but not for batch one. It was retained for this analysis.

Statistics, basis values and estimates for strength data and statistics for the modulus data are given in Table 4-4. The strength data and the B-basis values are shown graphically in Figure 4-3.

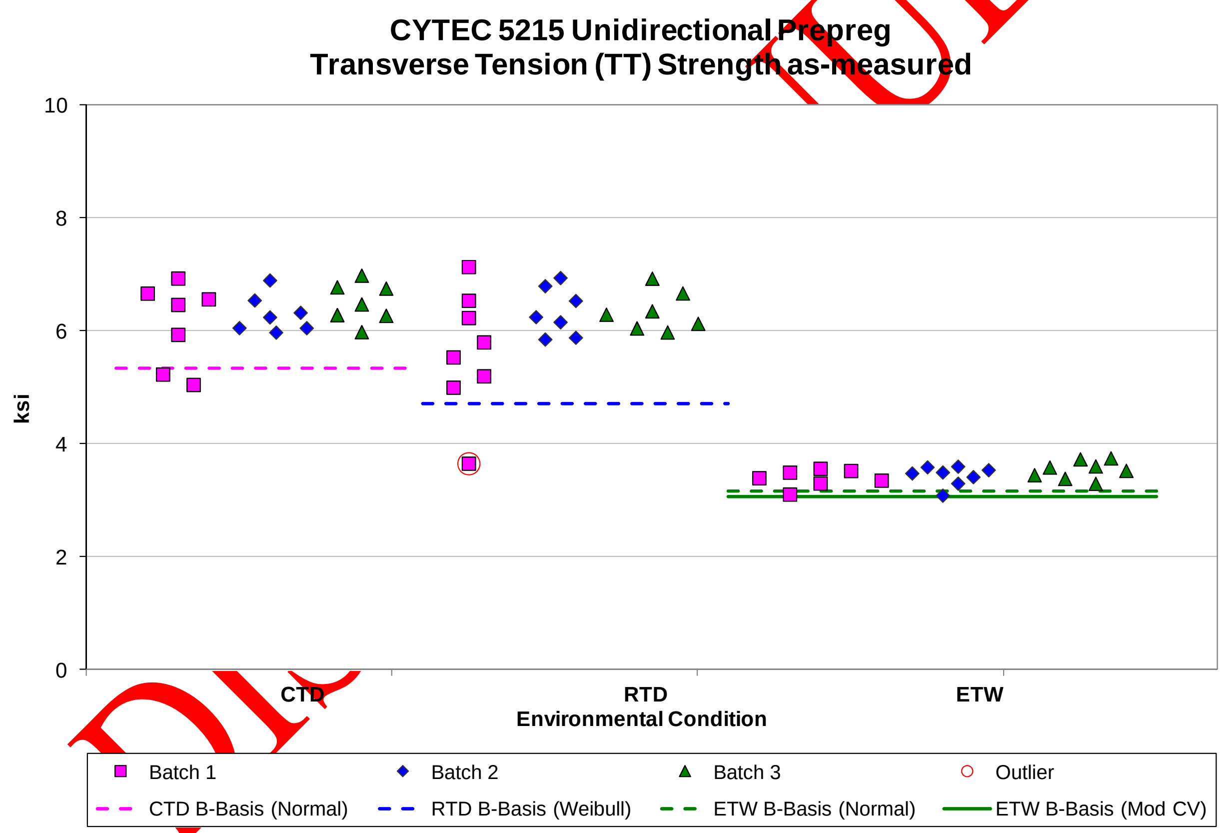

Figure 4-3: Batch Plot for TT strength as-measured

Transverse Tension Strength Basis Values and Statistics As-measured						
	Strength			Modulus		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	6.308	6.087	3.469	1.281	1.130	0.935
Stdev	0.507	0.766	0.167	0.022	0.014	0.019
CV	8.039	12.583	4.823	1.749	1.283	2.000
Mod CV	8.039	12.583	6.412	6.000	6.000	6.000
Min	5.049	3.655	3.090	1.242	1.103	0.890
Max	6.983	7.135	3.749	1.323	1.155	0.970
No. Batches	3	3	3	3	3	3
No. Spec.	21	22	24	21	22	24
Basis Values and Estimates						
B-basis Value	5.342	4.706	3.159			
A-estimate	4.653	3.502	2.937			
Method	Normal	Weibull	Normal			
Modified CV Basis Values and Estimates						
B-basis Value	NA	NA	3.057			
A-estimate	NA	NA	2.761			
Method	NA	NA	Normal			

Table 4-4: Statistics and Basis Values for TT data as-measured

4.3 Longitudinal (0°) Compression (LC)

The Longitudinal Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets. The strength values for 0° properties are computed via the formulas specified in section 2.5. For the CTD, RTD and ETW condition, equation 64 was used. For the ETD values, a different formula was required because there were no specimens tested in the ETD condition for the transverse compression and the mean modulus value for Transverse Compression is required by the formula that was used for the CTD, RTD and ETW conditions. Therefore, the ETD strength values were computed using equation 65.

The pooled datasets, both normalized and as-measured, had no diagnostic test failures and pooling was acceptable. There was one outlier. The highest value in batch one of the CTD condition was an outlier for both the as-measured and normalized datasets. It was an outlier for batch one only, not for the CTD condition. It was retained for this analysis.

Statistics, basis values and estimates are given for strength data in Table 4-6 and for the modulus data in Table 4-6. The data and the B-estimates are shown graphically in Figure 4-4.

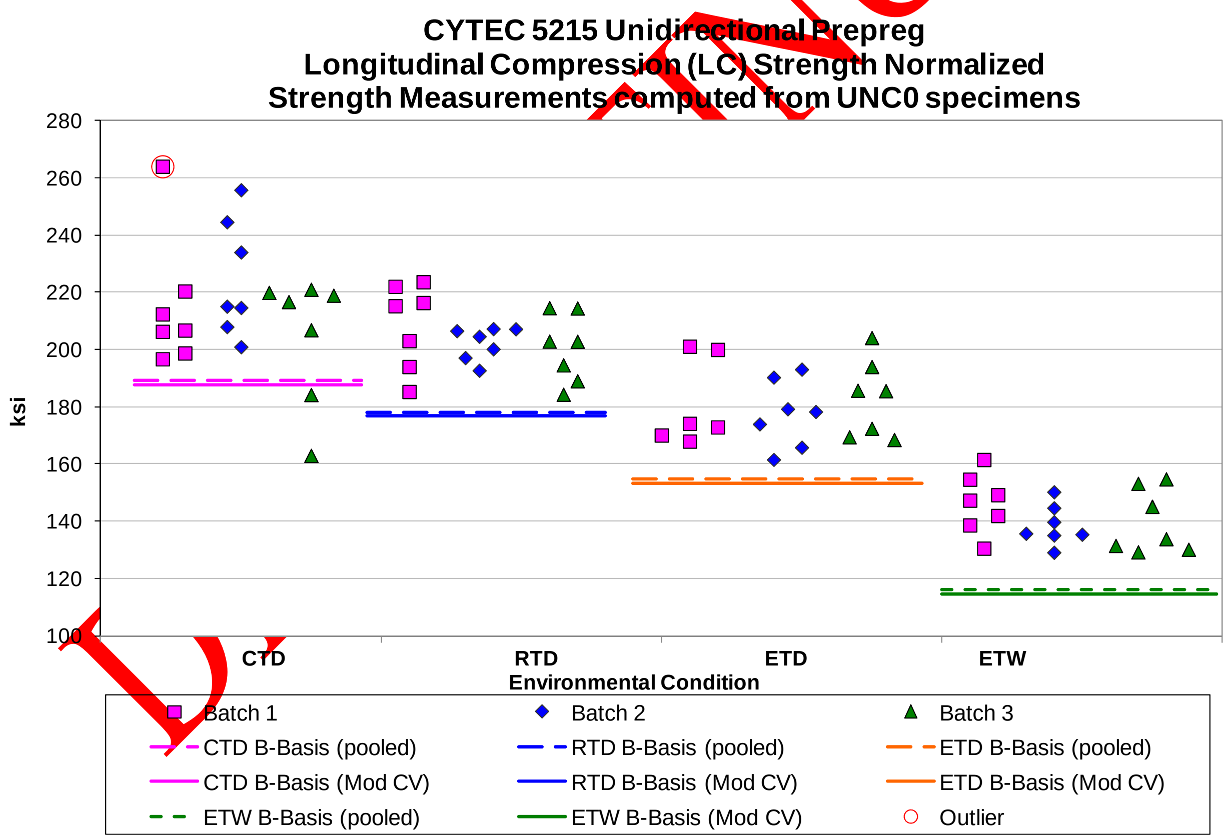

Figure 4-4 Batch plot for LC strength derived from UNC0 normalized

Longitudinal Compression Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	214.727	203.730	180.425	141.541	217.099	206.409	183.353	142.768
Stdev	22.495	11.360	12.914	9.779	23.479	11.400	13.317	10.557
CV	10.476	5.576	7.157	6.909	10.815	5.523	7.263	7.394
Mod CV	10.476	6.788	7.579	7.454	10.815	6.761	7.631	7.697
Min	162.988	184.360	161.575	129.141	164.256	189.650	162.723	128.637
Max	263.986	223.672	204.122	161.550	270.936	231.232	206.522	164.358
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	20	21	21	21	20	21
Basis Values and Estimates								
B-basis Value	189.108	178.112	154.685	115.922	190.463	179.774	156.590	116.133
A-Estimate	171.983	160.987	137.578	98.797	172.658	161.968	138.805	98.327
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	187.746	176.749	153.315	114.560	189.222	178.532	155.343	114.891
A-Estimate	169.710	158.713	135.299	96.524	170.587	159.897	136.729	96.256
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-5: Statistics and Basis Values for LC strength derived from UNC0

Longitudinal Compression Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	18.852	18.669	19.038	18.717	19.143	18.947	19.343	18.922
Stdev	0.717	0.382	0.321	0.350	0.709	0.337	0.318	0.277
CV	3.801	2.044	1.687	1.871	3.706	1.780	1.646	1.463
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Min	16.832	17.783	18.340	17.996	17.158	18.408	18.762	18.284
Max	20.300	19.325	19.620	19.229	20.592	19.615	19.876	19.279
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	21	21	21	18	21	21	21

Table 4-6: Statistics from LC modulus

4.4 Transverse (90º) Compression (TC)

Transverse Compression data is not normalized for unidirectional tape. The three environments could not be pooled due to a failure of Levene's test for equality of variance, but the RTD and ETW environments could be pooled together.   There were no outliers.

Statistics, basis values and estimates are given for strength and statistics for the modulus data in Table 4-7. The data and B-basis values are shown graphically in Figure 4-5.

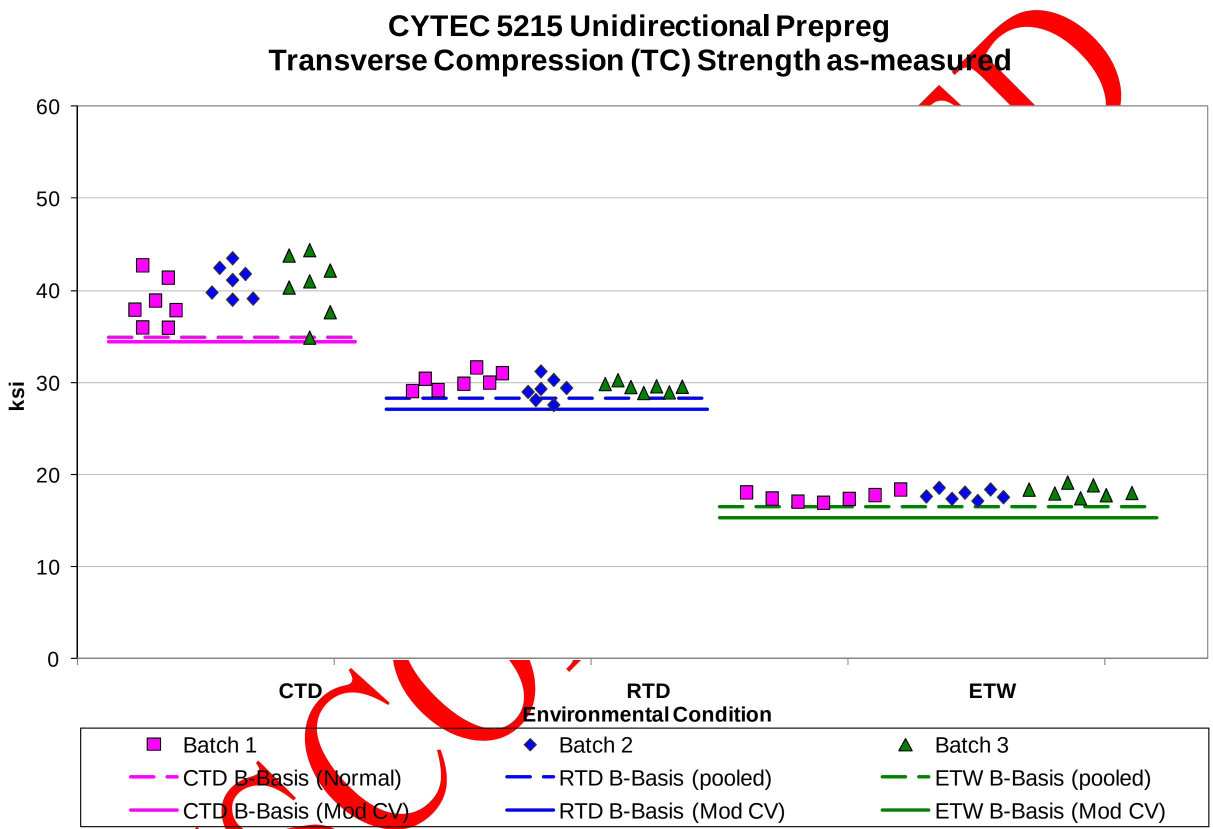

Figure 4-5: Batch Plot for TC strength as-measured

Transverse Compression Strength Basis Values and Statistics As-measured						
	Strength			Modulus		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	40.102	29.672	17.895	1.363	1.248	1.065
Stdev	2.714	0.973	0.594	0.110	0.027	0.026
CV	6.767	3.280	3.318	8.104	2.141	2.477
Mod CV	7.384	6.000	6.000	8.104	6.000	6.000
Min	34.903	27.589	16.968	1.193	1.187	1.013
Max	44.395	31.672	19.167	1.668	1.308	1.120
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	34.932	28.243	16.465			
A-estimate	31.247	27.260	15.482			
Method	Normal	pooled	pooled			
Modified CV Basis Values and Estimates						
B-basis Value	34.459	27.065	15.288			
A-estimate	30.440	25.272	13.495			
Method	Normal	pooled	pooled			

Table 4-7: Statistics and Basis Values for TC data as-measured

4.5 In-Plane Shear (IPS)

In-Plane Shear data is not normalized. There is 0.2% offset strength data for three environmental conditions (CTD, RTD & ETW). There is strength at 5% strain data for the RTD and ETW conditions but not the CTD condition. The CTD condition has data for peak strength before 5% strain.

There are data from only 13 specimens available for the strength at 5% strain data in the RTD condition, so only estimates are provided for that dataset. This dataset did not pass the normality test, so modified CV basis values are not provided.

The RTD 0.2% offset strength, the CTD peak strength before 5% strain and the ETW strength at 5% strain datasets fail the ADK test for batch-to-batch variability, so pooling was not appropriate and the single point ANOVA method was used. All three of these datasets passed the ADK test after applying the modified CV transform to the data, so modified CV basis values could be provided.

The CTD dataset for the 0.2% offset strength failed the normality test, so modified CV basis values are not provided. The CTD dataset for peak strength before 5% strain passed normality after the transform for the modified CV approach was applied, so modified CV values are provided for that dataset. Pooling was not appropriate for the 0.2% offset strength modified CV basis values due to a failure of Levene's test.

There was one outlier. The highest value in the RTD condition for the strength at 5% strain data was an outlier for the RTD condition. The outlier was in batch three, but since there was only one specimen available in that batch, it cannot be considered an outlier for the batch.

Statistics, estimates and basis values are given for the strength data in Table 4-8 and modulus data in Table 4-9. The data, B-estimates and B-basis values are shown graphically for the 0.2% offset strength in Figure 4-6 and for the CTD peak strength before 5% strain and the RTD and ETW strength at 5% strain in Figure 4-7.

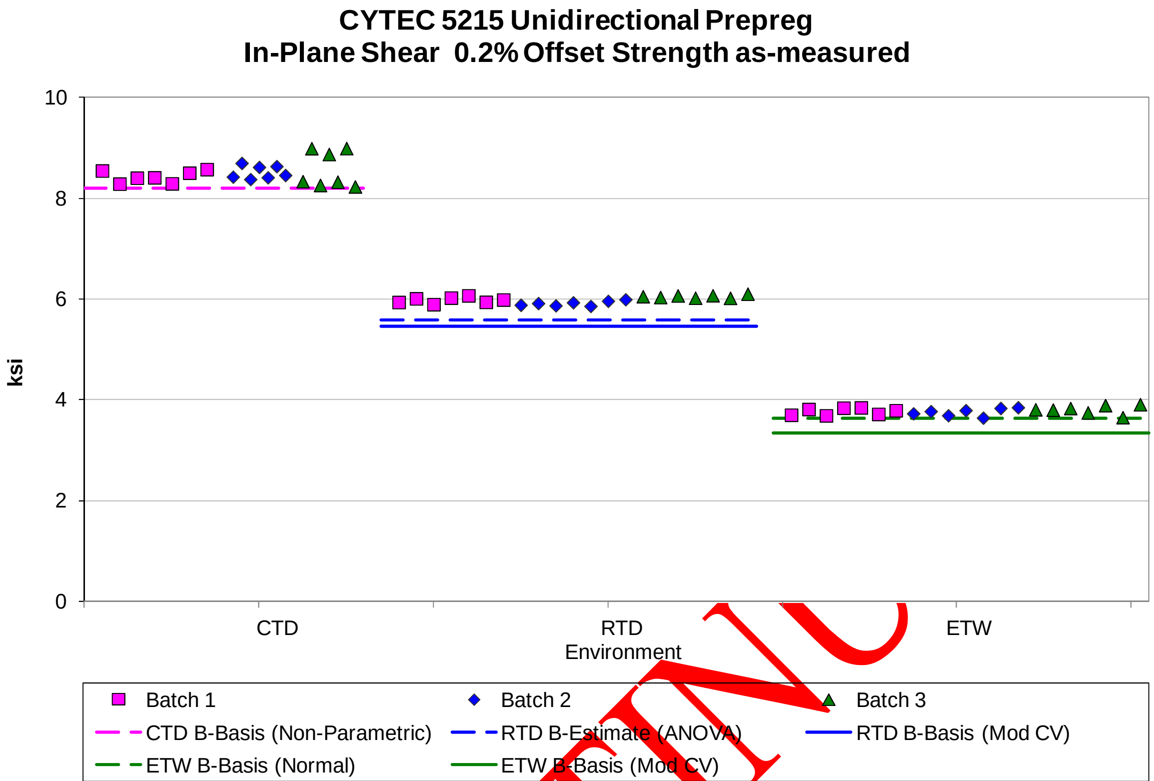

Figure 4-6: Batch plot for IPS for 0.2% offset strength as-measured

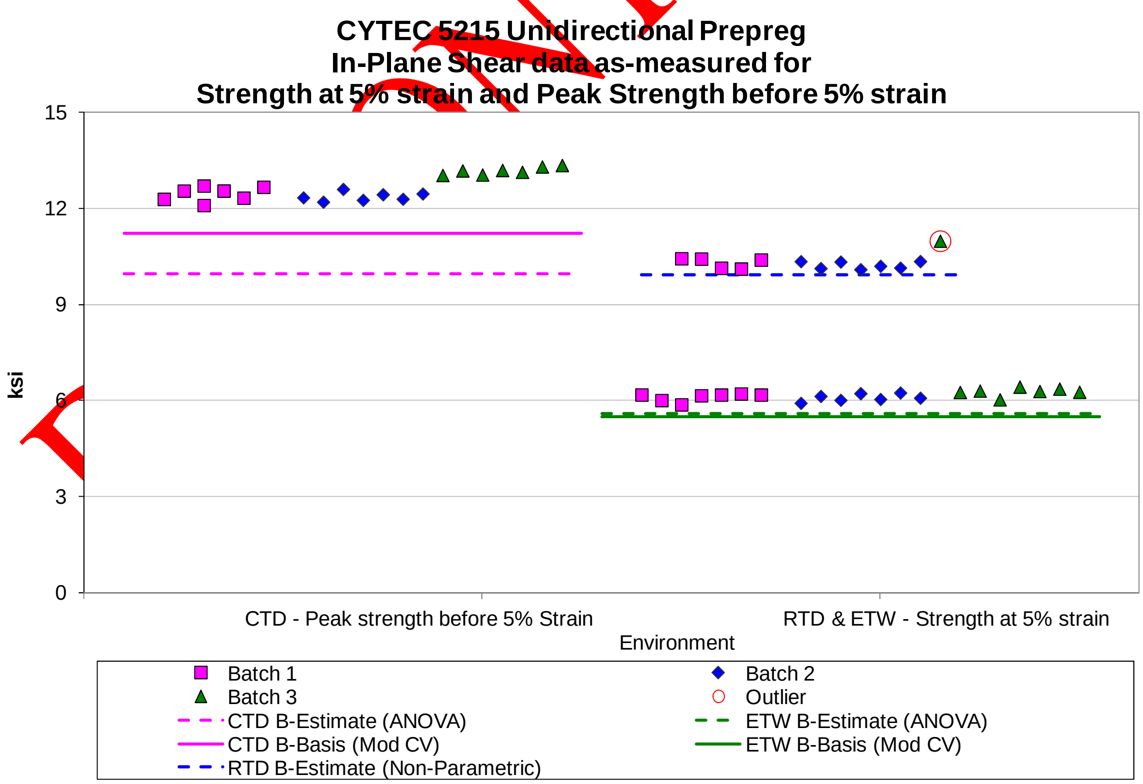

Figure 4-7: Batch plot for IPS data for peak strength before 5% strain and strength at 5% strain

In-Plane Shear Strength Basis Values and Statistics As-measured						
	CTD - Peak Strength before 5% strain	Strength at 5% Strain		0.2% Offset Strength		
Env		RTD	ETW	CTD	RTD	ETW
Mean	12.680	10.325	6.169	8.512	5.989	3.783
Stdev	0.404	0.238	0.143	0.226	0.073	0.076
CV	3.183	2.307	2.322	2.656	1.221	2.017
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	12.111	10.103	5.880	8.236	5.865	3.648
Max	13.361	10.995	6.435	8.997	6.108	3.914
No. Batches	3	3	3	3	3	3
No. Spec.	21	13	21	21	21	21
Basis Values and Estimates						
B-basis Value				8.197		3.638
B-estimate	9.962	9.930	5.582		5.576	
A-estimate	8.021	8.531	5.162	7.336	5.281	3.534
Method	ANOVA	Non-Parametric	ANOVA	Non-Parametric	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	11.231	NA	5.464	NA	5.304	3.351
A-estimate	10.198	NA	4.961	NA	4.816	3.043
Method	Normal	NA	Normal	NA	Normal	Normal

Table 4-8: Statistics and Basis Values for IPS Strength data

In-Plane Shear Modulus Statistics As-measured			
Env	CTD	RTD	ETW
Mean	0.673	0.542	0.403
Stdev	0.019	0.009	0.007
CV	2.856	1.733	1.859
Mod CV	6.000	6.000	6.000
Min	0.650	0.527	0.390
Max	0.714	0.557	0.418
No. Batches	3	3	3
No. Spec.	21	21	21

Table 4-9: Statistics from IPS Modulus data

4.6 Short Beam Strength (SBS)

The Short Beam Strength data is not normalized. The data from each of the four environmental conditions (CTD, RTD, ETD and ETW) failed the ADK test for batch-to-batch variability, so pooling was not appropriate and the single point ANOVA method was used. All four of these datasets passed the ADK test after applying the modified CV transform to the data, so modified CV basis values could be provided. The pooled dataset containing all four conditions failed the Levene's test but passed with the ETW condition removed.

There were three outliers. One outlier was in batch one of the ETD data. Two outliers were in the ETW data, one in batch one and the other in batch three. All three outliers were low and outliers for their respective batches only, not for their respective conditions. All three outliers were retained for this analysis.

Statistics, estimates and basis values are given for SBS data in Table 4-10. The data, B-estimates, and the B-basis values are shown graphically in Figure 4-8.

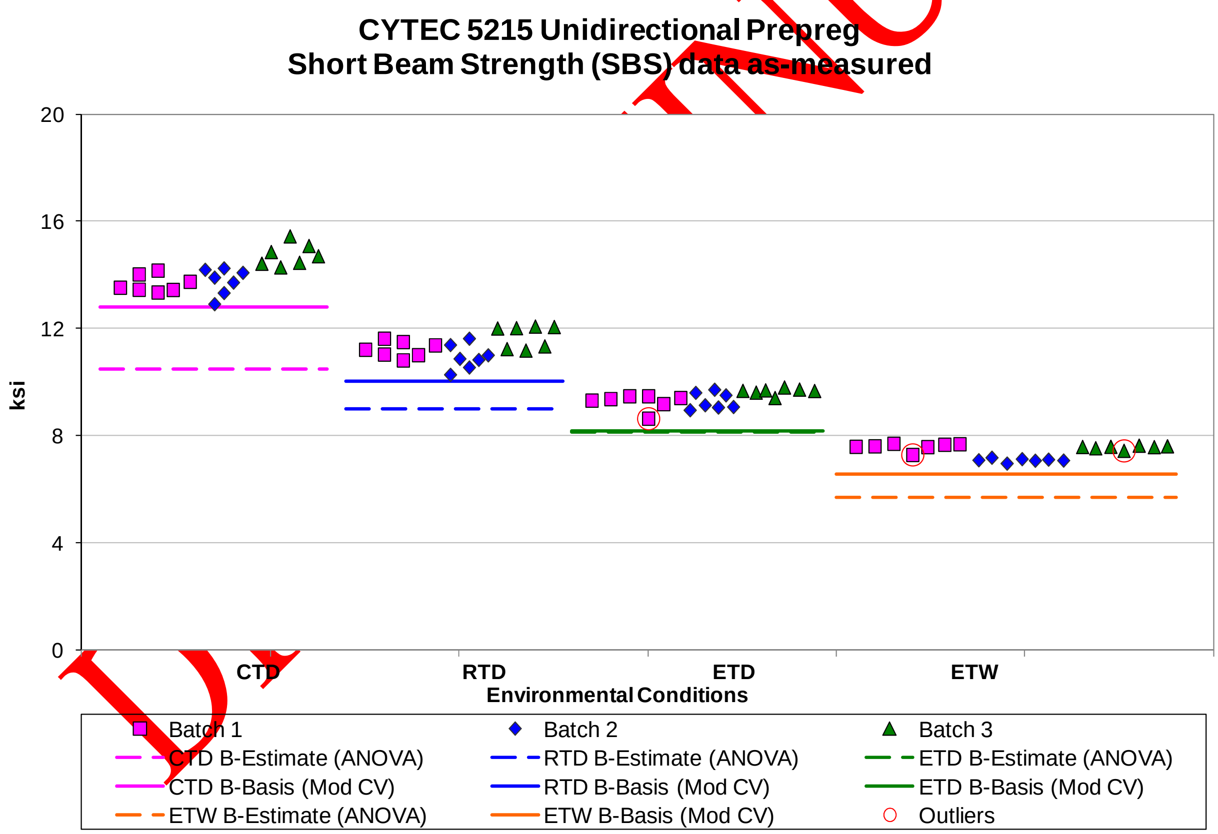

Figure 4-8: Batch plot for SBS as-measured

Short Beam Strength (SBS) Basis Values and Statistics As-measured				
Env	CTD	RTD	ETD	ETW
Mean	14.071	11.293	9.410	7.418
Stdev	0.635	0.499	0.304	0.253
CV	4.510	4.419	3.233	3.417
Mod CV	6.255	6.210	6.000	6.000
Min	12.918	10.282	8.642	6.968
Max	15.450	12.083	9.809	7.707
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-Estimate	10.474	9.004	8.134	5.691
A-estimate	7.906	7.370	7.223	4.457
Method	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	12.814	10.036	8.154	6.570
A-estimate	11.965	9.187	7.305	5.966
Method	pooled	pooled	pooled	Normal

Table 4-10: Statistics and Basis Values for SBS data

4.7 Unnotched Tension (UNT0)

The Unnotched Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

All datasets, both normalized and as-measured and for all three environmental conditions, failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used. All three of the as-measured datasets (CTD, RTD & ETW) as well as the CTD and RTD normalized datasets passed the ADK test after applying the modified CV transform to the data, so pooling was appropriate for the modified CV basis values. The only exception to this was the normalized ETW dataset. The normalized ETW dataset also fails the normality test, so modified CV estimates are not appropriate. Basis values estimates computed with an override of the ADK test are provided instead. The Weibull distribution had the best fit for the dataset.

There was one outlier, it was the lowest value in batch one of the ETW dataset. It was an outlier for both the normalized and as-measured datasets. It was an outlier only for batch one and not for the ETW condition.

Statistics, estimates and basis values are given for strength data in Table 4-11 and for the modulus data in Table 4-12. The normalized data, the B-estimates and B-basis values are shown graphically in Figure 4-9.

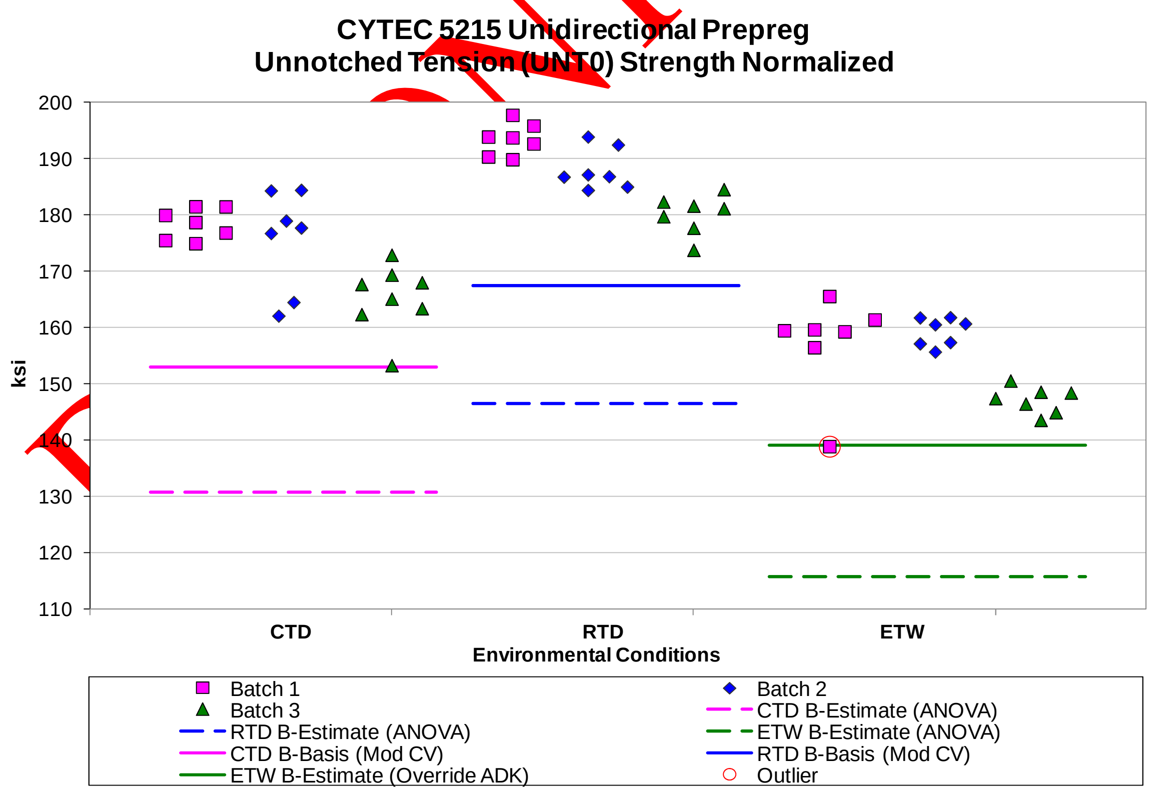

Figure 4-9: Batch Plot for UNT0 strength normalized

Unnotched Tension (UNT0) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	172.776	187.281	154.598	173.974	188.590	155.648
Stdev	8.439	6.447	7.428	8.149	5.914	7.472
CV	4.884	3.443	4.805	4.684	3.136	4.801
Modified CV	6.442	6.000	6.402	6.342	6.000	6.400
Min	153.325	173.830	138.923	155.639	175.541	138.822
Max	184.489	197.824	165.614	187.774	197.920	167.947
No. Batches	3	3	3	3	3	3
No. Spec.	22	21	21	22	21	21
Basis Values and Estimates						
B-estimate	130.666	146.474	115.630	141.064	153.882	120.791
A-estimate	100.598	117.340	87.813	117.564	129.104	95.910
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	153.062	167.488		155.414	169.949	137.007
A-estimate	139.447	153.891		142.815	157.365	124.424
Method	pooled	pooled		pooled	pooled	pooled
Basis values estimates with override of ADK test results						
B-estimate			139.124			
A-estimate			123.061			
Method			Weibull			

Table 4-11: Statistics and Basis Values for UNT0 Strength data

Unnotched Tension (UNT0) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	11.158	11.150	11.178	11.237	11.230	11.256
Stdev	0.169	0.125	0.144	0.216	0.160	0.190
CV	1.519	1.118	1.289	1.919	1.424	1.691
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	10.826	10.919	10.990	10.738	10.990	10.850
Max	11.402	11.391	11.619	11.485	11.572	11.642
No. Batches	3	3	3	3	3	3
No. Spec.	22	21	22	22	21	22

Table 4-12: Statistics from UNT0 Modulus data

4.8 Unnotched Compression (UNC0)

The Unnotched Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The normalized data had no diagnostic test failures and pooling was acceptable. The as-measured data failed Levene's test for equality of variance but passed after applying the modified CV Transform. Pooling was acceptable for the as-measured data from the CTD, RTD and ETD conditions, with the single point method, normal distribution being used for the as-measured ETW condition. All four conditions were pooled to compute the modified CV basis values for the as measured data.

There was one outlier. The highest value in batch one of the CTD condition was an outlier for both the as-measured and normalized datasets. It was an outlier for batch one only, not for the CTD condition. It was retained for this analysis.

Statistic, estimates and basis values are given for strength data in Table 4-13 and for the modulus data in Table 4-14. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-10

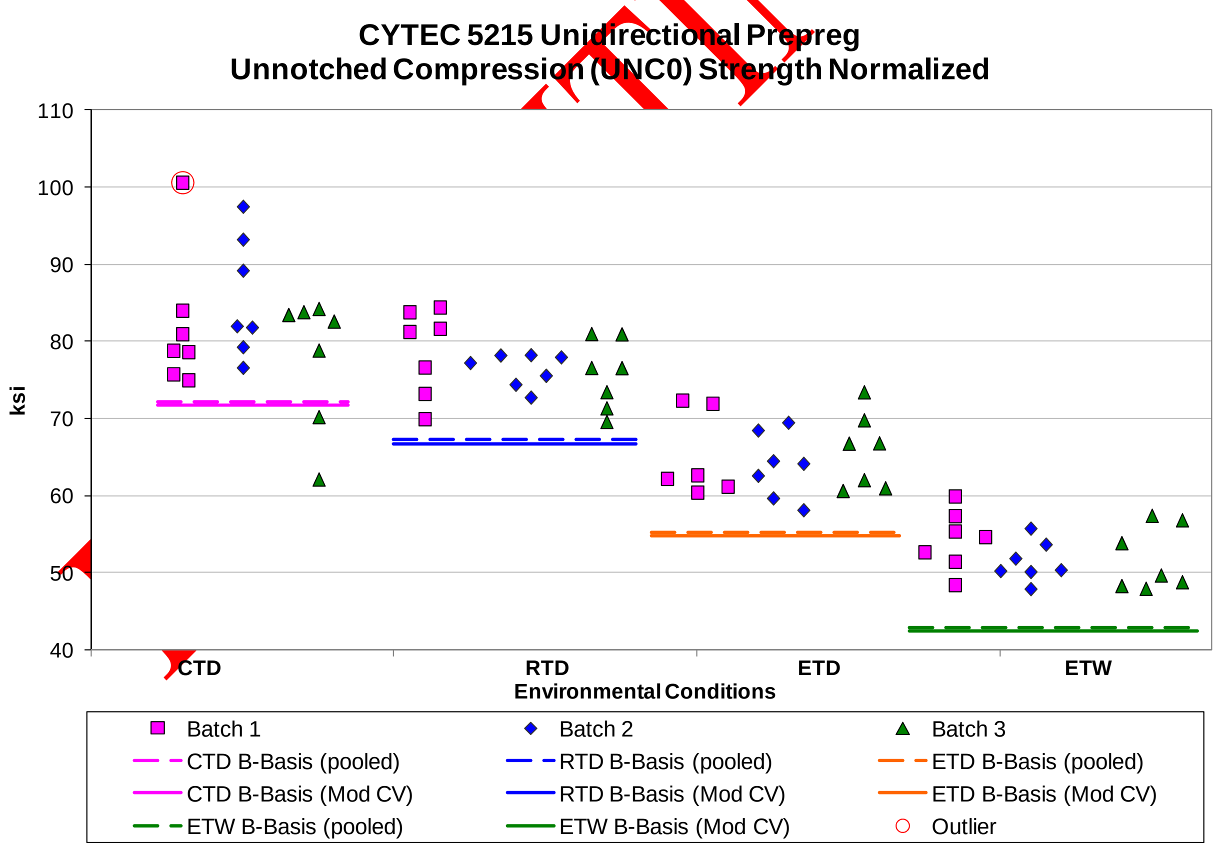

Figure 4-10: Batch Plot for UNC0 strength normalized

Unnotched Compression (UNC0) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	81.834	76.882	64.899	52.493	82.581	77.761	65.460	52.891
Stdev	8.573	4.287	4.645	3.627	8.931	4.295	4.754	3.911
CV	10.476	5.576	7.157	6.909	10.815	5.523	7.263	7.394
Modified CV	10.476	6.788	7.579	7.454	10.815	6.761	7.631	7.697
Min	62.116	69.573	58.119	47.894	62.481	71.447	58.094	47.655
Max	100.607	84.408	73.423	59.914	103.061	87.113	73.731	60.889
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	20	21	21	21	20	21
Basis Values and Estimates								
B-basis Value	72.208	67.257	55.227	42.867	71.559	66.739	54.386	45.440
A-estimate	65.773	60.822	48.800	36.433	64.108	59.288	46.945	40.129
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	Normal
Modified CV Basis Values and Estimates								
B-basis Value	71.704	66.752	54.721	42.363	72.140	67.320	54.969	42.449
A-estimate	64.932	59.980	47.956	35.591	65.161	60.340	47.997	35.470
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-13: Statistics and Basis Values for UNC0 Strength data

Unnotched Compression (UNC0) Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	7.021	7.241	6.848	7.381	7.083	7.324	6.906	7.459
Stdev	0.384	0.170	0.245	0.495	0.389	0.170	0.237	0.479
CV	5.476	2.342	3.576	6.713	5.493	2.325	3.427	6.423
Mod CV	6.738	6.000	6.000	7.356	6.746	6.000	6.000	7.212
Min	5.771	6.825	6.444	6.972	5.860	7.010	6.442	7.101
Max	7.540	7.509	7.255	9.319	7.710	7.638	7.272	9.356
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	21	20	21	21	21	20

Table 4-14: Statistics from UNC0 Modulus data

4.9 Quasi Isotropic (25/50/25) Unnotched Tension (UNT1)

The Quasi Isotropic Unnotched Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

There were no test failures in the normalized datasets, so pooling across all three environmental conditions was acceptable. The as-measured ETW dataset failed the normality test, as did the as-measured pooled dataset, so pooling across all three environments was not appropriate for the as-measured data. However, the as-measured CTD and RTD datasets could be pooled.

There was one outlier. It was the lowest value in batch one of the normalized ETW dataset. It was an outlier only for batch one, not for the ETW condition and only for the normalized dataset, not for the as-measured dataset. It was retained for this analysis.

Statistics, basis values and estimates are given for UNT1 strength data in Table 4-15and for the modulus data in Table 4-16. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-11.

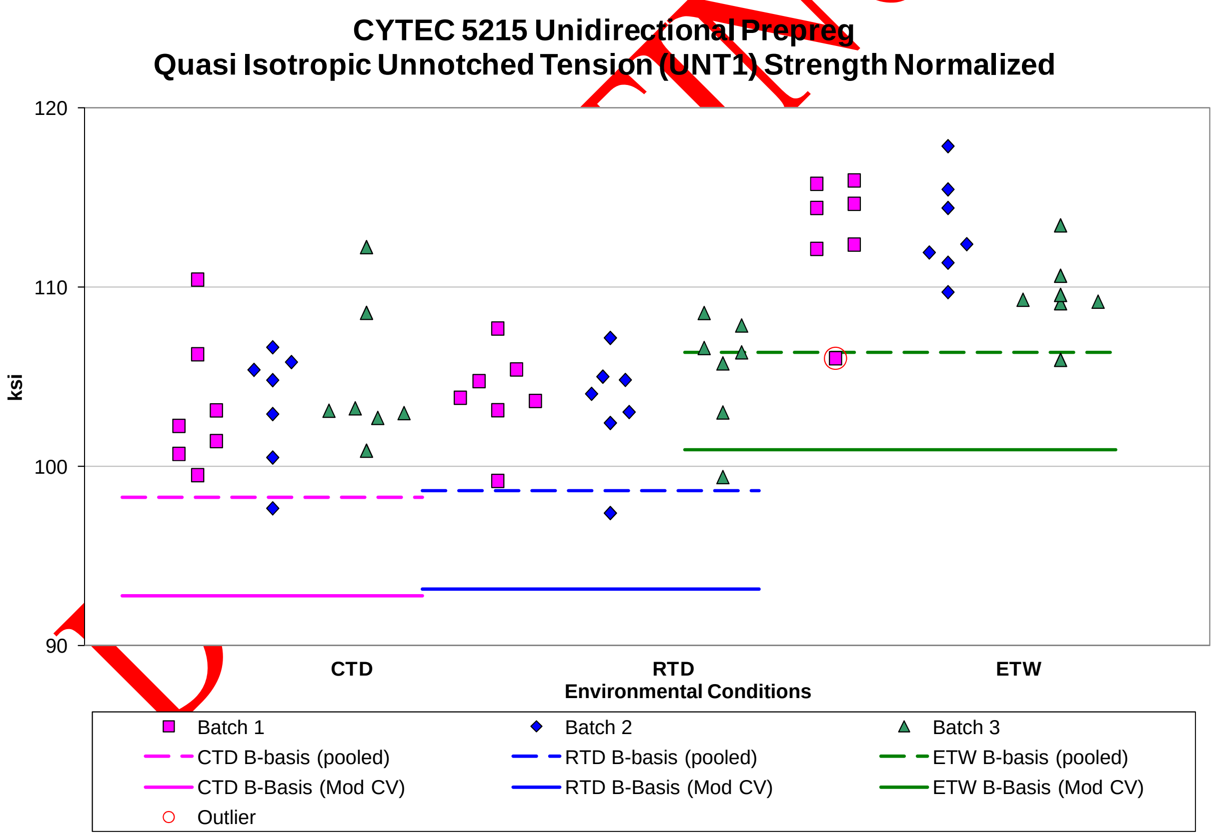

Figure 4-11: Batch Plot for UNT1 strength normalized

Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	103.866	104.246	111.984	104.084	104.304	111.828
Stdev	3.580	2.923	3.212	3.760	3.173	3.992
CV	3.447	2.804	2.868	3.613	3.043	3.570
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	97.666	97.401	105.947	96.957	96.362	104.884
Max	112.235	108.560	117.861	112.030	110.478	119.772
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	98.248	98.628	106.366	97.914	98.135	104.481
A-estimate	94.453	94.833	102.571	93.671	93.892	99.582
Method	pooled	pooled	pooled	pooled	pooled	Lognormal
Modified CV Basis Values and Estimates						
B-basis Value	92.790	93.171	100.908	92.998	93.219	NA
A-estimate	85.308	85.689	93.426	85.374	85.594	NA
Method	pooled	pooled	pooled	pooled	pooled	NA

Table 4-15: Statistics and Basis Values for UNT1 Strength data

Unnotched Tension (UNT1) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	7.948	7.691	7.599	7.965	7.694	7.587
Stdev	0.111	0.194	0.177	0.146	0.186	0.188
CV	1.394	2.526	2.326	1.836	2.419	2.478
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	7.753	7.174	7.247	7.672	7.159	7.307
Max	8.128	7.999	7.933	8.217	8.060	7.900
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21

Table 4-16: Statistics from UNT1 Modulus data

4.10 “Soft” (10/80/10) Unnotched Tension (UNT2)

The "Soft" Unnotched Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The as-measured CTD dataset and both the normalized and as-measured ETW datasets failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used for those datasets. The CTD and RTD normalized datasets could be pooled to compute basis values. All three datasets that failed the ADK test initially passed it after applying the modified CV transform to the data, so pooling all three environments was appropriate for the modified CV basis values for both normalized and as-measured data. There were no outliers.

Statistics, basis values and estimates are given for UNT2 strength data in Table 4-17 and for the modulus data in Table 4-18. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-12

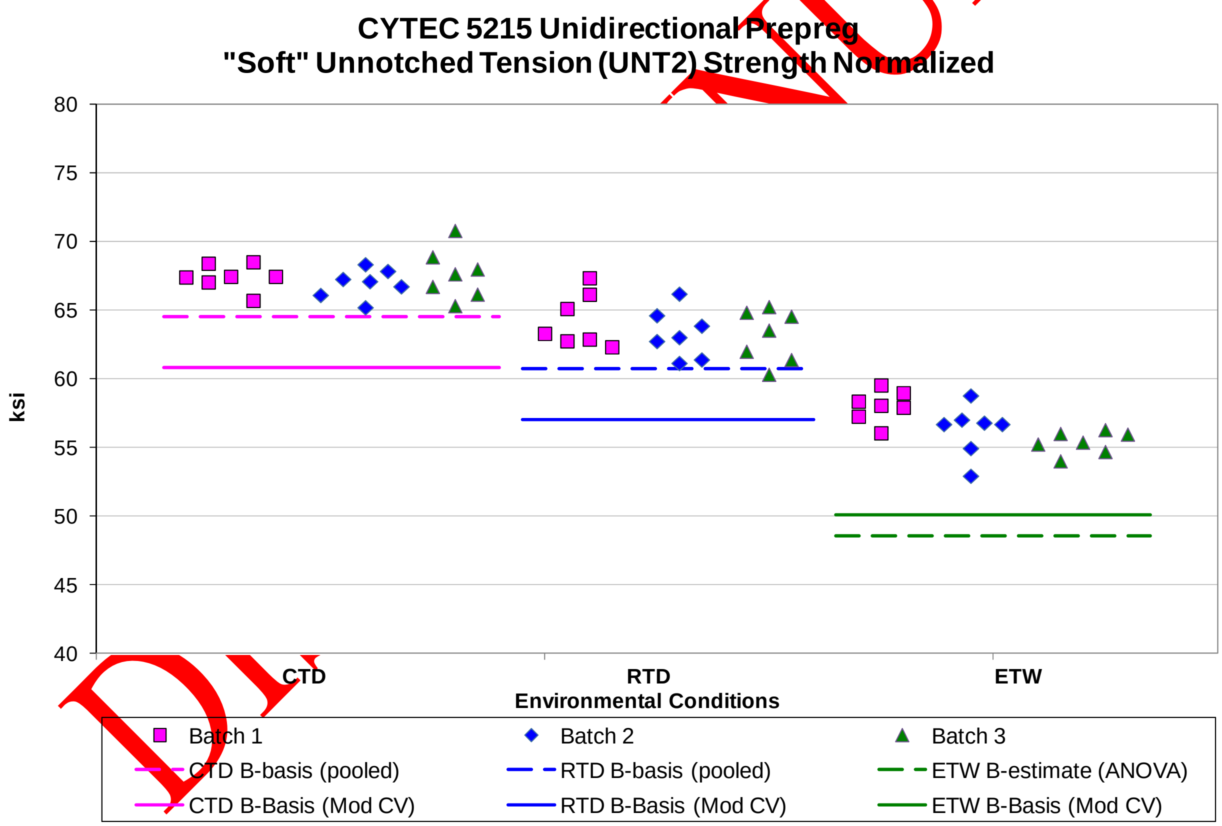

Figure 4-12: Batch Plot for UNT2 strength normalized

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	67.324	63.552	56.554	67.421	63.805	56.833
Stdev	1.298	1.853	1.696	1.673	1.990	1.829
CV	1.928	2.916	2.999	2.481	3.120	3.219
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	65.193	60.320	52.934	64.244	60.104	52.194
Max	70.781	67.340	59.542	71.799	67.056	59.629
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	64.487	60.715			60.013	
B-estimate			48.568	59.058		47.301
A-estimate	62.536	58.763	42.867	53.089	57.310	40.496
Method	pooled	pooled	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	60.826	57.054	50.056	60.902	57.285	50.314
A-estimate	56.437	52.664	45.666	56.498	52.882	45.910
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-17: Statistics and Basis Values for UNT2 Strength data

Unnotched Tension (UNT2) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	4.948	4.721	4.331	4.954	4.739	4.351
Stdev	0.123	0.196	0.111	0.106	0.179	0.085
CV	2.477	4.141	2.554	2.136	3.775	1.944
Modified CV	6.000	6.071	6.000	6.000	6.000	6.000
Min	4.717	4.385	4.019	4.745	4.498	4.085
Max	5.184	5.178	4.525	5.166	5.229	4.477
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21

Table 4-18: Statistics from UNT2 Modulus data

4.11 "Hard" (50/40/10) Unnotched Tension (UNT3)

The "Hard" Unnotched Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The normalized ETW dataset and both the normalized and as-measured RTD datasets failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used for those datasets. All three datasets that failed the ADK test initially passed it after applying the modified CV transform to the data, so pooling all three environments was appropriate for the modified CV basis values for both normalized and as-measured data.

There was one outlier. The highest value in batch three of the CTD data was an outlier. It was an outlier only for batch three, not for the CTD condition. It was an outlier for both the normalized and as-measured datasets.

Statistics and basis values are given for UNT3 strength data in Table 4-19 and for the modulus data in Table 4-20. The normalized data, the B-estimates and B-basis values are shown graphically in Figure 4-13.

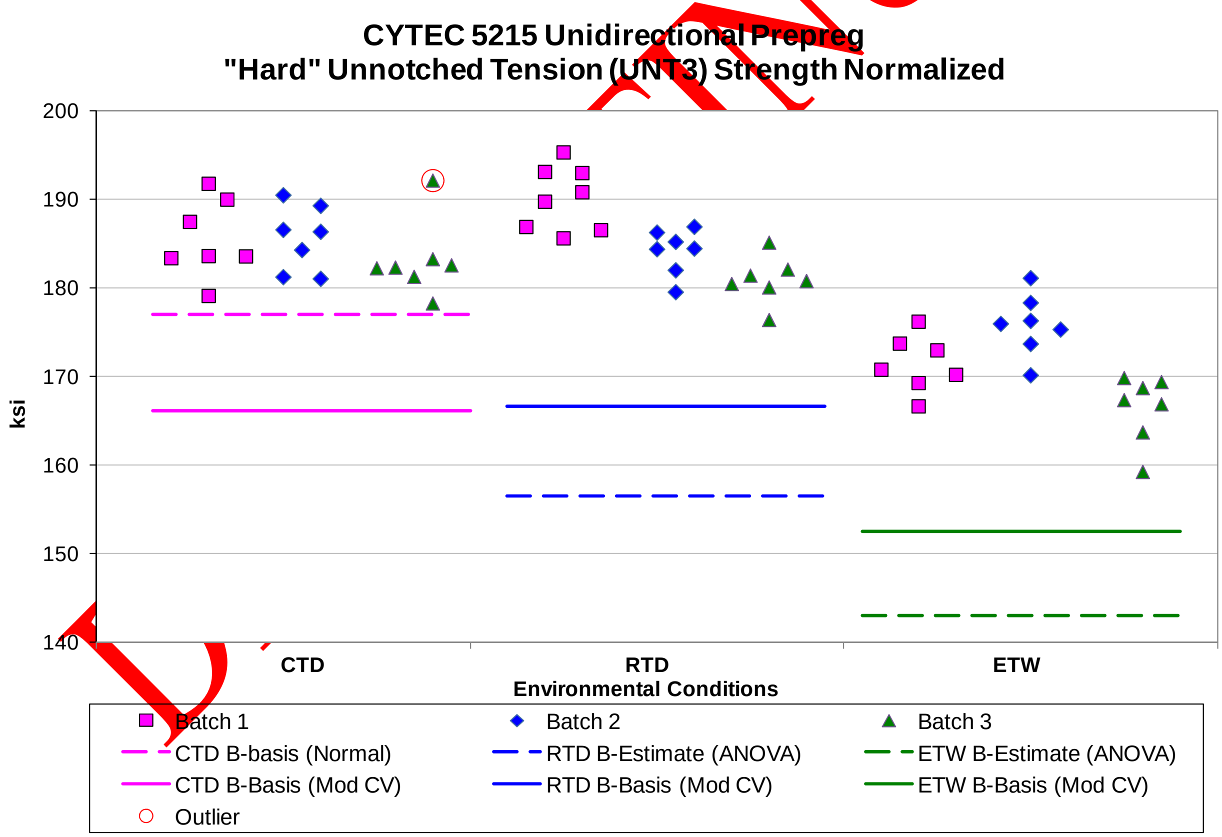

Figure 4-13: Batch Plot for UNT3 strength normalized

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	184.761	185.266	171.214	183.815	184.317	170.337
Stdev	4.088	4.880	5.130	4.017	5.157	3.976
CV	2.212	2.634	2.996	2.186	2.798	2.334
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	178.251	176.380	159.232	176.410	174.573	160.854
Max	192.128	195.298	181.103	192.268	195.127	176.384
No. Batches	3	3	3	3	3	3
No. Spec.	21	22	21	21	22	21
Basis Values and Estimates						
B-basis Value	176.974			176.162		162.762
B-estimate		156.415	142.971		155.842	
A-estimate	171.422	135.815	122.809	170.706	135.511	157.362
Method	Normal	ANOVA	ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	166.040	166.626	152.494	165.191	165.771	151.712
A-estimate	153.402	153.973	139.856	152.617	153.184	139.139
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-19: Statistics and Basis Values for UNT3 Strength data

Unnotched Tension (UNT3) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	12.334	12.367	11.908	12.271	12.304	11.840
Stdev	0.187	0.302	0.208	0.163	0.320	0.239
CV	1.514	2.445	1.750	1.329	2.605	2.021
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	11.941	11.941	11.507	12.041	11.816	11.258
Max	12.735	13.030	12.232	12.609	13.051	12.282
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	20	21	21	20

Table 4-20: Statistics from UNT3 Modulus data

4.12 Quasi Isotropic (25/50/25) Unnotched Compression 1 (UNC1)

The Quasi Isotropic Unnotched Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The UNC1 data had no diagnostic test failures and no outliers. Statistics, basis values and estimates are given for UNC1 strength data in Table 4-21 and for the modulus data in Table 4-22. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-14.

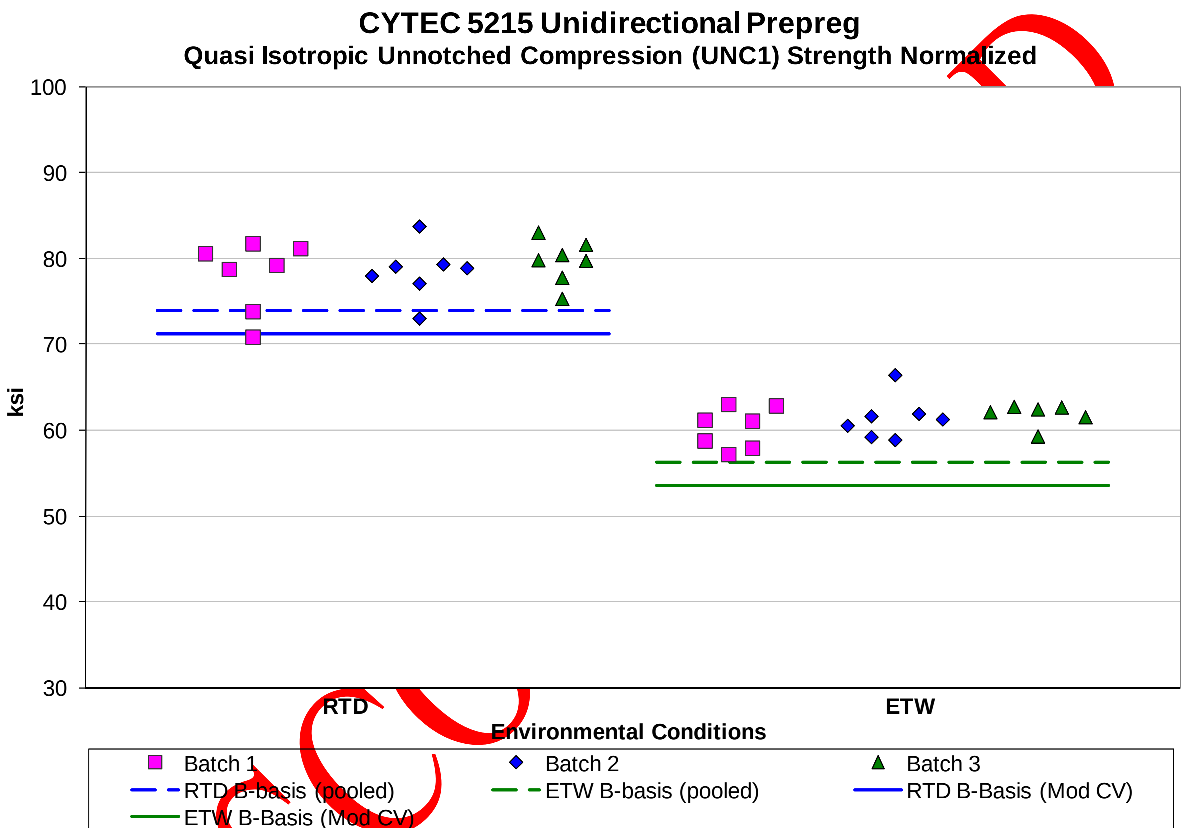

Figure 4-14: Batch plot for UNC1 strength normalized

Unnotched Compression (UNC1) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	78.737	61.072	79.365	61.701
Stdev	3.242	2.129	3.534	2.040
CV	4.117	3.486	4.453	3.307
Modified CV	6.059	6.000	6.227	6.000
Min	70.895	57.200	71.050	57.650
Max	83.771	66.456	85.735	66.102
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	73.874	56.209	74.247	56.583
A-estimate	70.529	52.865	70.728	53.064
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	71.194	53.530	71.622	53.958
A-estimate	66.007	48.342	66.298	48.634
Method	pooled	pooled	pooled	pooled

Table 4-21: Statistics and Basis Values for UNC1 Strength data

Unnotched Compression (UNC1) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	7.177	6.732	7.234	6.779
Stdev	0.095	0.295	0.107	0.279
CV	1.325	4.375	1.478	4.121
Modified CV	6.000	6.188	6.000	6.060
Min	7.009	6.339	6.997	6.402
Max	7.404	7.235	7.464	7.212
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-22: Statistics from UNC1 Modulus data

4.13 “Soft” (10/80/10) Unnotched Compression (UNC2)

The "Soft" Unnotched Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets

Neither the normalized nor the as-measured RTD datasets passed the ADK test, so the single point ANOVA method was used. After applying the modified CV transformation to the data, the normalized RTD dataset passed the ADK test but the as-measured RTD dataset did not. The normalized RTD and ETW datasets could be pooled to compute modified CV basis values. Estimates made using the modified CV method are provided for the as-measured RTD dataset, but they are considered estimates only due to the failure of the ADK test.

There was one outlier. It was the lowest value in batch three of the as-measured RTD dataset. It was an outlier only for batch 3, not for the RTD condition and only for the as-measured dataset, not for the normalized dataset.

Statistics and basis values are given for UNC2 strength data in Table 4-23 and for the modulus data in Table 4-24. The normalized data, the B-estimates and the B-basis values are shown graphically in Figure 4-15.

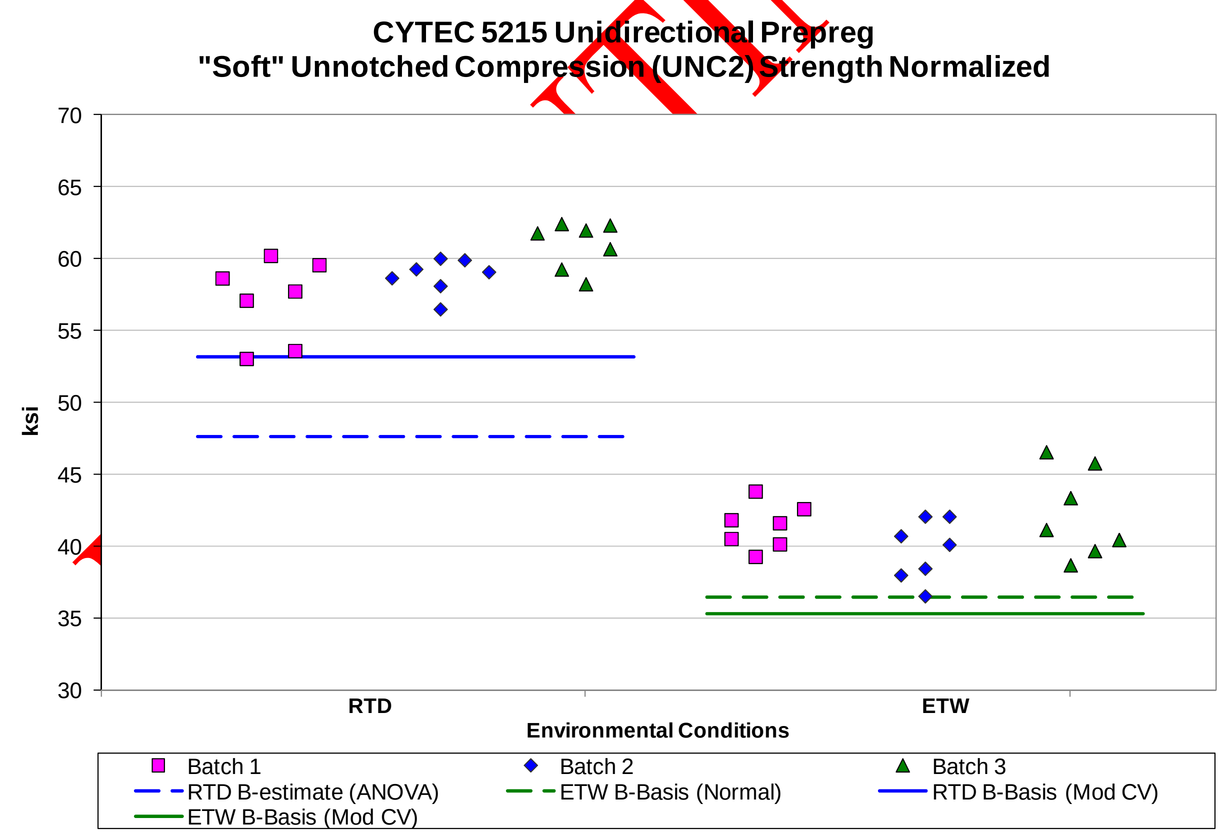

Figure 4-15: Batch plot for UNC2 strength normalized

Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	58.951	41.111	59.921	41.654
Stdev	2.488	2.454	2.817	2.442
CV	4.220	5.970	4.701	5.862
Modified CV	6.110	6.985	6.350	6.931
Min	53.042	36.532	53.826	36.554
Max	62.421	46.549	64.343	47.058
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value		36.435		37.002
B-estimate	47.636		45.871	
A-estimate	39.560	33.102	35.842	33.686
Method	ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	53.175	35.335		36.152
B-estimate			52.670	
A-estimate	49.202	31.363	47.505	32.234
Method	pooled	pooled	Normal	Normal

Table 4-23: Statistics and Basis Values for UNC2 Strength data

Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	4.553	3.835	4.627	3.892
Stdev	0.072	0.077	0.078	0.102
CV	1.574	2.015	1.676	2.630
Modified CV	6.000	6.000	6.000	6.000
Min	4.452	3.736	4.500	3.739
Max	4.717	3.998	4.752	4.085
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-24: Statistics from UNC2 Modulus data

4.14 “Hard” (50/40/10) Unnotched Compression (UNC3)

The "Hard" Unnotched Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The normalized RTD and ETW datasets could be pooled. The as-measured ETW condition dataset and the as-measured pooled dataset failed the normality test, so pooling was not appropriate for the as-measured data. Due to the non-normality of the as-measured ETW dataset, no modified CV basis values are provided for that dataset. There were no other diagnostic test failures and no outliers.

Statistics, basis values and estimates are given for UNC3 strength data in Table 4-25 and for the modulus data in Table 4-26. The normalized data and the B-basis values are shown graphically in Figure 4-16.

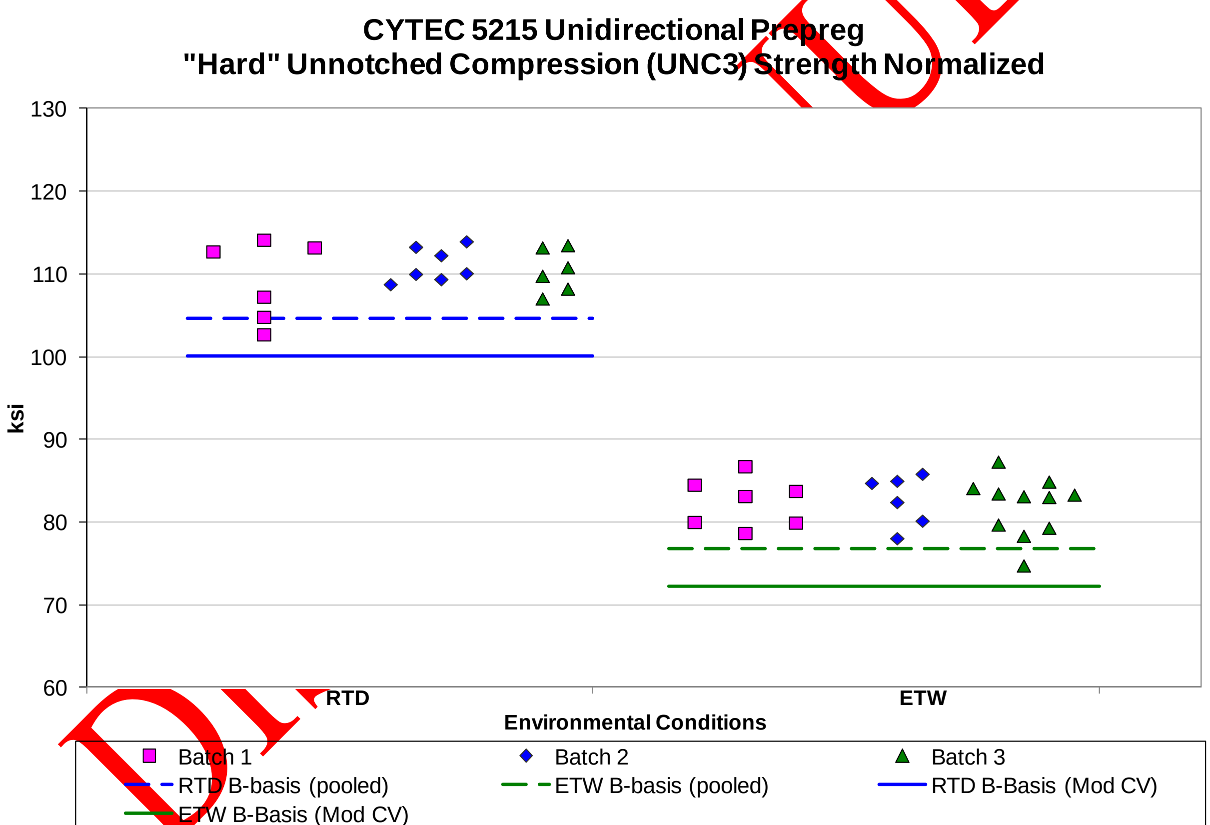

Figure 4-16: Batch plot for UNC3 strength normalized

Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	110.304	82.299	111.416	83.285
Stdev	3.245	3.140	2.862	3.305
CV	2.942	3.815	2.568	3.968
Modified CV	6.000	6.000	6.000	6.000
Min	102.739	74.790	105.421	75.630
Max	114.173	87.343	115.599	88.576
No. Batches	3	3	3	3
No. Spec.	19	24	19	24
Basis Values and Estimates				
B-basis Value	104.612	76.722	105.839	74.655
A-estimate	100.749	72.832	101.879	62.858
Method	pooled	pooled	Normal	Non-parametric
Modified CV Basis Values and Estimates				
B-basis Value	100.058	72.259	98.386	NA
A-estimate	93.103	65.257	89.147	NA
Method	pooled	pooled	Normal	NA

Table 4-25: Statistics and Basis Values for UNC3 Strength data

Unnotched Compression (UNC3) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	11.352	10.748	11.476	10.841
Stdev	0.161	0.512	0.168	0.555
CV	1.416	4.765	1.467	5.122
Modified CV	6.000	6.383	6.000	6.561
Min	11.068	9.871	11.185	9.909
Max	11.752	11.547	11.791	11.762
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-26: Statistics from UNC3 Modulus data

4.15 Quasi Isotropic (25/50/25) Open Hole Tension (OHT1)

The Quasi Isotropic Open Hole Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

All OHT1 datasets failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used. All datasets passed the ADK test after applying the modified CV transform to the data, so pooling all three environments was appropriate for the modified CV basis values for both normalized and as-measured data.

There were three outliers. Two in the RTD condition and one in the ETW condition. The highest value in batch one of the RTD condition was an outlier for both batch one and the RTD condition. It was an outlier for both the normalized and the as-measured datasets. The highest value in batch three of the RTD condition was an outlier only for batch three and only for the as-measured dataset. The highest value in batch two of the ETW condition was an outlier for batch two only, not for the ETW condition. It was an outlier for both the normalized and the as-measured datasets. All three outliers were retained for this analysis.

Statistics, basis values and estimates are given for OHT1 strength data in Table 4-27. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-17.

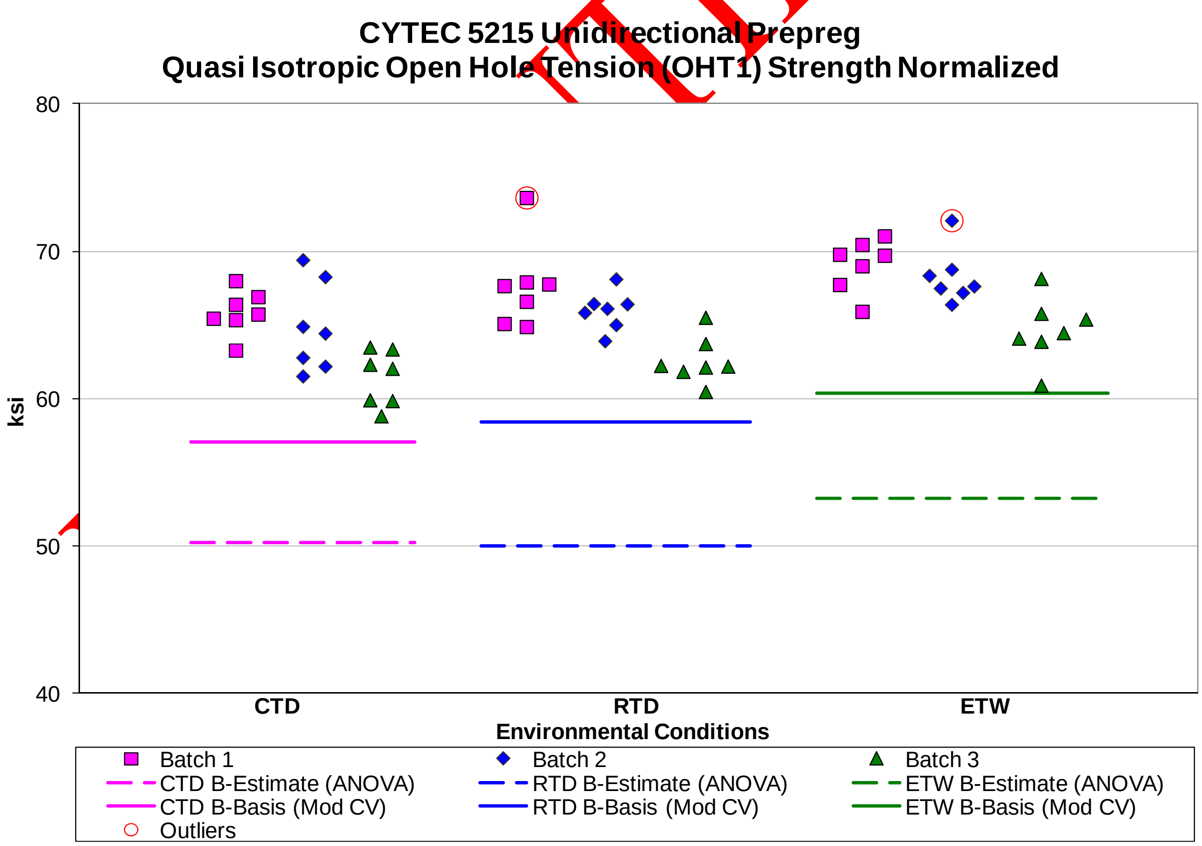

Figure 4-17: Batch Plot for OHT1 strength normalized

Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	64.033	65.418	67.354	64.477	65.799	67.578
Stdev	2.870	2.913	2.699	2.484	2.738	2.696
CV	4.482	4.453	4.007	3.852	4.162	3.990
Modified CV	6.241	6.226	6.004	6.000	6.081	6.000
Min	58.841	60.488	60.917	59.188	61.671	61.286
Max	69.425	73.651	72.105	68.118	73.624	72.636
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-estimate	50.211	49.988	53.272	52.410	52.378	55.299
A-estimate	40.346	38.973	43.220	43.796	42.797	46.535
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	57.051	58.436	60.373	57.603	58.925	60.704
A-estimate	52.335	53.720	55.656	52.959	54.281	56.061
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-27: Statistics and Basis Values for OHT1 Strength data

4.16 “Soft” (10/80/10) Open Hole Tension (OHT2)

The "Soft" Open Hole Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The as-measured CTD dataset failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used. The as-measured RTD and ETW datasets failed Levene's test for equality of variance, so those datasets could not be pooled together. The as-measured CTD datasets passed the ADK test after applying the modified CV transform to the data and the pooled data set passed the normality test, so pooling all three environments was appropriate for the modified CV basis values. The normalized OHT2 datasets had no diagnostic test failures, so pooling was appropriate for computing all basis values and estimates. There were no outliers.

Statistics, basis values and estimates are given for OHT2 strength data in Table 4-28. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-18.

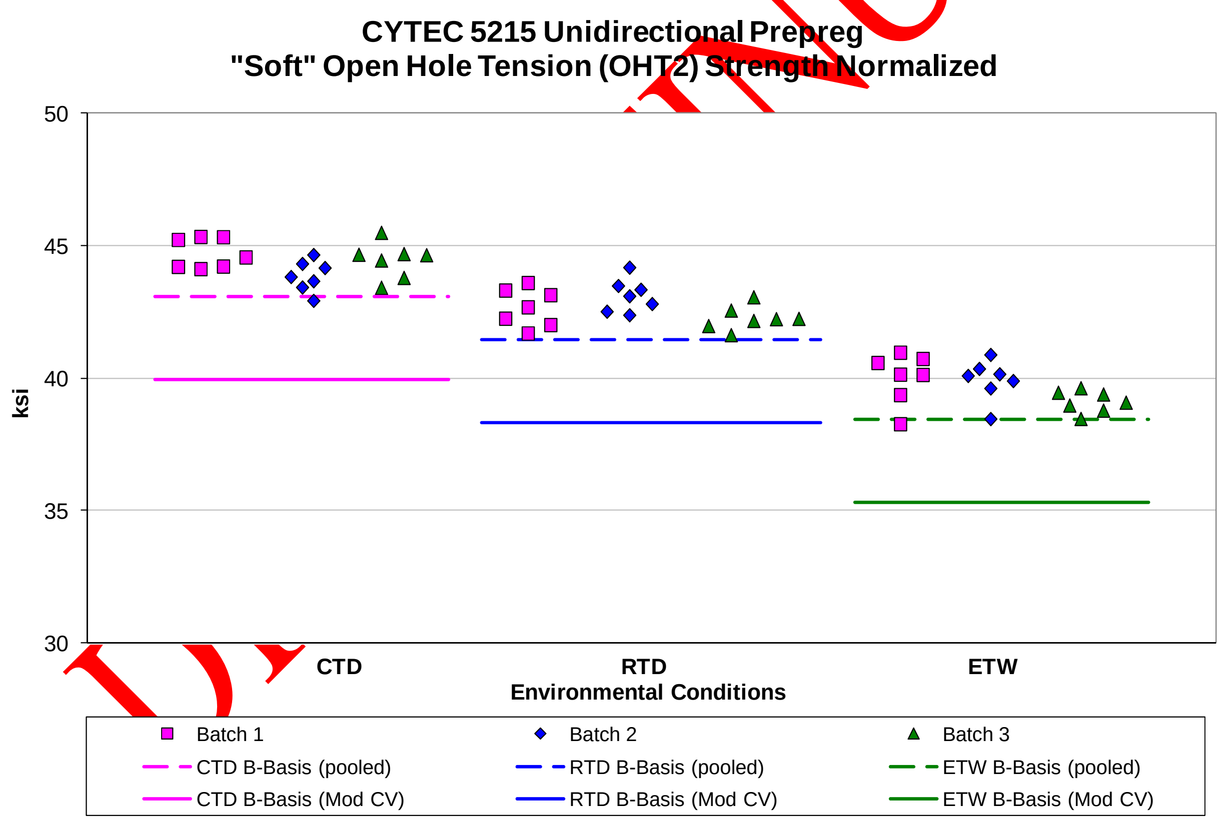

Figure 4-18: Batch Plot for OHT2 strength normalized

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	44.348	42.691	39.693	44.681	42.913	40.160
Stdev	0.685	0.675	0.812	0.931	0.743	0.996
CV	1.544	1.582	2.046	2.084	1.731	2.479
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	42.932	41.636	38.274	42.605	41.580	38.723
Max	45.499	44.187	40.975	46.033	44.517	41.759
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	43.091	41.434	38.437		41.498	38.264
B-estimate				39.250		
A-estimate	42.242	40.586	37.588	35.374	40.490	36.912
Method	pooled	pooled	pooled	ANOVA	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	39.961	38.304	35.306	40.259	38.491	35.738
A-estimate	36.997	35.340	32.343	37.271	35.504	32.751
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-28: Statistics and Basis Values for OHT2 Strength data

4.17 “Hard” (50/40/10) Open Hole Tension (OHT3)

The "Hard" Open Hole Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

All OHT3 datasets, both normalized and as-measured, failed the ADK test even after the modified CV transform was applied to the data. The CV in all cases was over 8%, so the modified CV method could not be applied. Estimates of basis values were computed using the ANOVA method. These are excessively low, which is not unusual in this type of circumstance. In addition, estimates of basis values are provided with an override of the ADK test results. Caution is recommended regarding the use of the basis values computed by overriding the ADK test results. Batch one values are consistently higher than batch three values across the environments, which is a counter-indication for using an override with respect to pooling the environments (See section 4.3.10 of CMH-17 Rev G), so the single point method was used for these estimates.

There were two outliers. The highest value in batch two of the CTD condition was an outlier for batch two only, not for the CTD condition. It was an outlier for both the normalized and for the as-measured datasets. The lowest value in batch one of the RTD data was an outlier for batch one only, not for the RTD condition. It was an outlier only for the normalized dataset, not for the as-measured dataset. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for OHT3 strength data in Table 4-29. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-19.

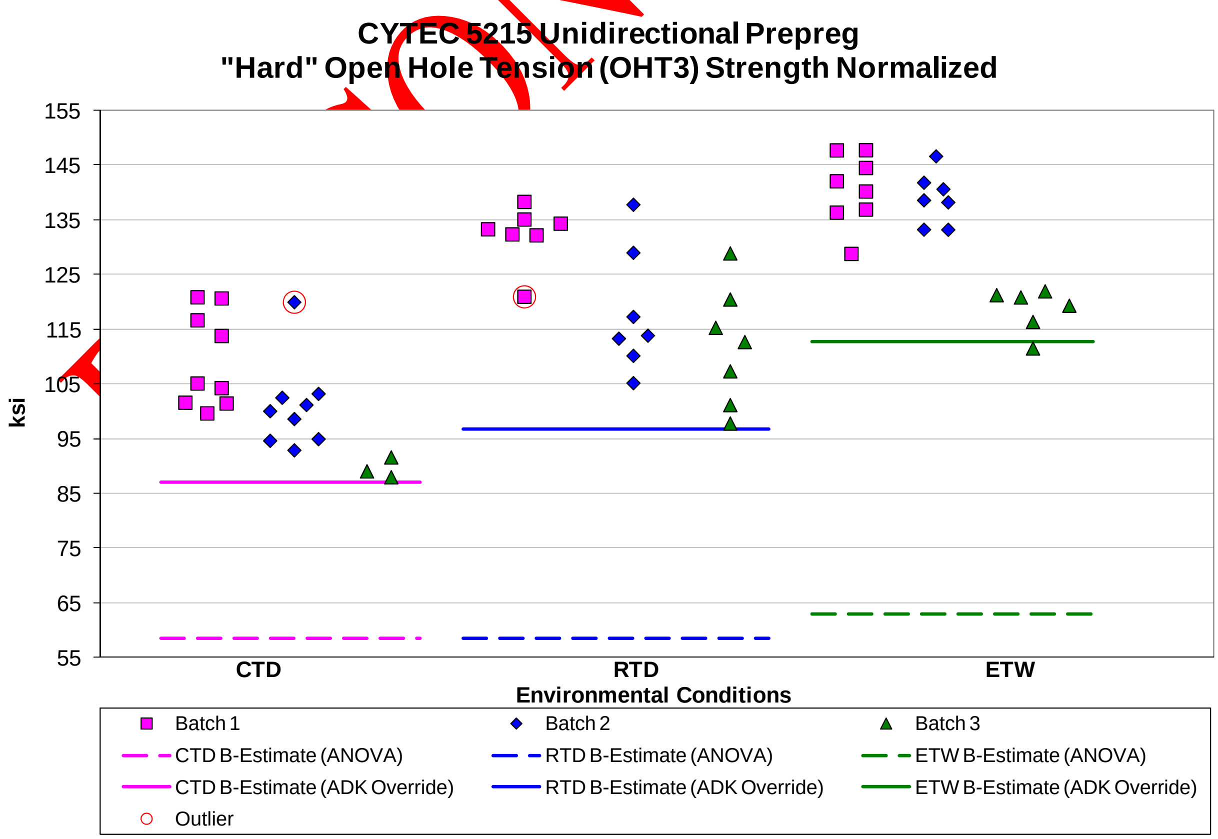

Figure 4-19: Batch Plot for OHT3 strength normalized

Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	102.201	120.850	133.411	103.248	121.551	133.863
Stdev	9.451	12.650	10.920	9.639	12.765	10.314
CV	9.248	10.468	8.186	9.336	10.502	7.705
Modified CV	9.248	10.468	8.186	9.336	10.502	7.853
Min	88.020	97.864	111.572	88.707	98.919	113.988
Max	120.925	138.369	147.813	125.049	142.702	148.109
No. Batches	3	3	3	3	3	3
No. Spec.	25	21	22	25	21	22
Basis Value Estimates						
B-estimate	58.476	58.581	62.966	65.154	62.610	68.061
A-estimate	27.224	14.132	12.669	37.913	20.538	21.079
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Basis values estimates with override of ADK test results						
B-estimate	87.093	96.752	112.816	87.055	97.234	114.411
A-estimate	61.457	79.571	98.105	77.241	79.897	100.517
Method	Non-Parametric	Normal	Normal	Lognormal	Normal	Normal

Table 4-29: Statistics and Basis Values for OHT3 Strength data

4.18 Quasi Isotropic (25/50/25) Filled Hole Tension (FHT1)

The Quasi Isotropic Filled Hole Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The RTD and ETW datasets, both normalized and as-measured, failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used for those datasets. The RTD and ETW datasets, both normalized and as-measured, passed the ADK test after applying the modified CV transform to the data, so pooling all three environments was appropriate for the modified CV basis values.

There was one outlier. The lowest value in batch two of the as-measured RTD dataset was an outlier for batch two, but not for the RTD condition. It was an outlier only for the as-measured RTD dataset, not for the normalized RTD dataset.

Statistics, estimates and basis values are given for FHT1 strength data in Table 4-30. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-20 .

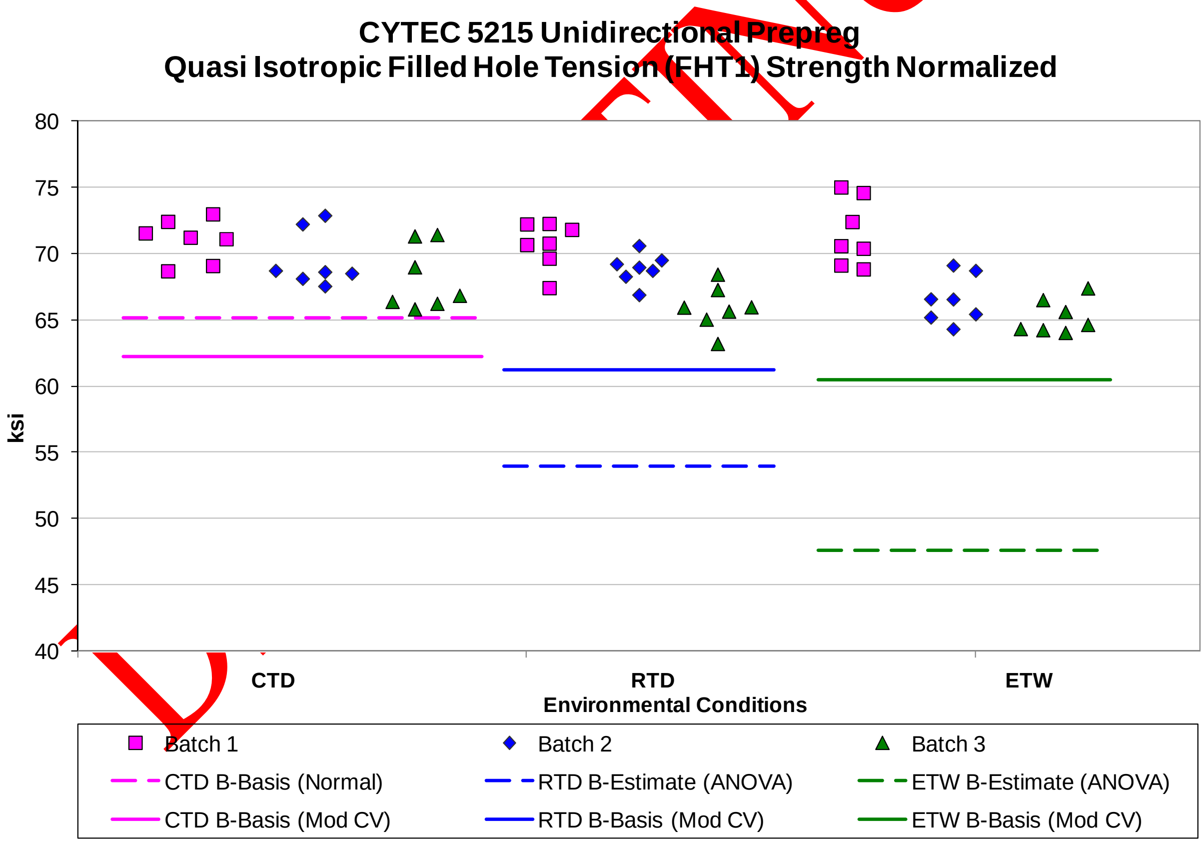

Figure 4-20: Batch plot for FHT1 strength normalized

Filled-Hole Tension (FHT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	69.566	68.508	67.802	69.784	68.673	67.644
Stdev	2.307	2.478	3.334	2.452	2.358	2.970
CV	3.316	3.617	4.917	3.514	3.433	4.390
Modified CV	6.000	6.000	6.458	6.000	6.000	6.195
Min	65.826	63.215	64.046	65.814	64.379	64.170
Max	72.994	72.265	75.028	73.900	72.409	74.268
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	65.171			65.113		
B-estimate		53.987	47.602		56.574	52.185
A-estimate	62.038	43.620	33.180	61.783	47.937	41.149
Method	Normal	ANOVA	ANOVA	Normal	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	62.265	61.207	60.501	62.581	61.470	60.440
A-estimate	57.333	56.275	55.569	57.715	56.604	55.574
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-30: Statistics and Basis Values for FHT1 Strength data

4.19 "Soft" (10/80/10) Filled Hole Tension (FHT2)

The "Soft" Filled Hole Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The normalized and as-measured RTD and the normalized ETW datasets failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used for those datasets. The RTD and ETW datasets, both normalized and as-measured, passed the ADK test after applying the modified CV transform to the data. Both the as-measured and normalized CTD datasets failed the normality test and so did the pooled datasets when the CTD condition was included. Pooling the RTD and ETW environments was appropriate for the modified CV basis values. No modified CV basis values are provided for the CTD datasets due to the failure of the normality test.

There were three outliers. The lowest value in batch one of the CTD data was an outlier for both batch one and the CTD condition. It was an outlier for both the normalized and as-measured datasets. The lowest value in batch three of the as-measured RTD dataset was an outlier for batch three, but not for the RTD condition. It was an outlier for the as-measured RTD dataset, but not for the normalized RTD dataset. The highest value in batch one of the normalized RTD dataset was an outlier for batch one, but not for the RTD condition. It was an outlier only for the normalized RTD dataset, not for the as-measured RTD dataset.

Statistics, estimates and basis values are given for FHT2 strength data in Table 4-31. The normalized data, the B-estimates and B-basis values are shown graphically in Figure 4-21.

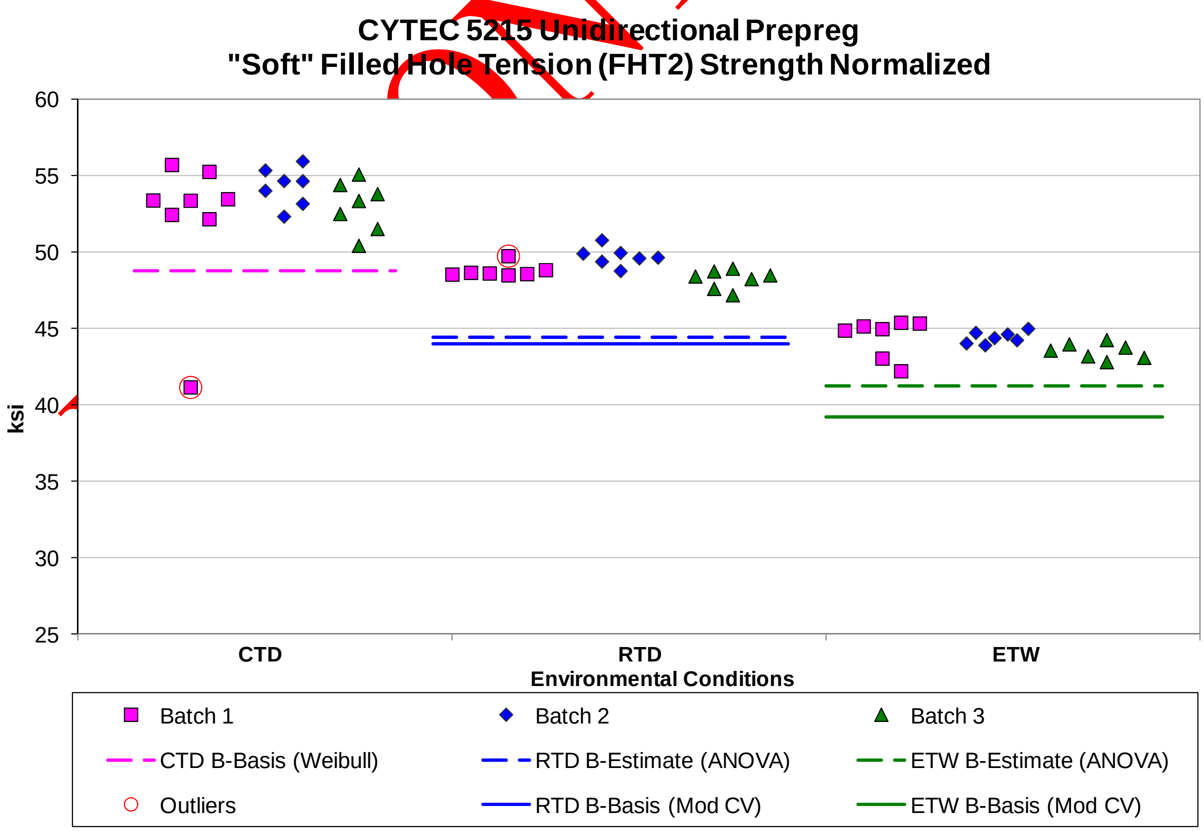

Figure 4-21: Batch plot for FHT2 strength normalized

Filled-Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	53.095	48.911	44.128	53.303	48.794	44.378
Stdev	3.015	0.826	0.890	3.069	1.031	0.680
CV	5.679	1.689	2.017	5.757	2.112	1.533
Modified CV	6.840	6.000	6.000	6.878	6.000	6.000
Min	41.167	47.195	42.220	41.149	46.354	42.550
Max	55.943	50.784	45.390	56.672	50.636	45.261
No. Batches	3	3	3	3	3	3
No. Spec.	22	21	21	22	21	21
Basis Values and Estimates						
B-basis Value	48.787			48.577		43.082
B-estimate		44.387	41.211		42.841	
A-estimate	44.122	41.158	39.130	43.553	38.591	42.158
Method	Weibull	ANOVA	ANOVA	Weibull	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	NA	43.955	39.172	NA	43.831	39.416
A-estimate	NA	40.547	35.763	NA	40.419	36.003
Method	NA	pooled	pooled	NA	pooled	pooled

Table 4-31: Statistics and Basis Values for FHT2 Strength data

4.20 "Hard" (50/40/10) Filled Hole Tension (FHT3)

The "Hard" Filled Hole Tension data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

RTD and ETW datasets, both normalized and as-measured, and the normalized CTD dataset failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used for those datasets. The normalized CTD dataset and both the normalized and as-measured ETW datasets passed the ADK test after applying the modified CV transform to the data, so modified CV basis values are provided. The normalized RTD dataset did not pass the ADK test even after the modified CV transform was applied, so only estimates can be provided for that dataset. There were no outliers.

Statistics, estimates and basis values are given for FHT3 strength data in Table 4-32. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-22.

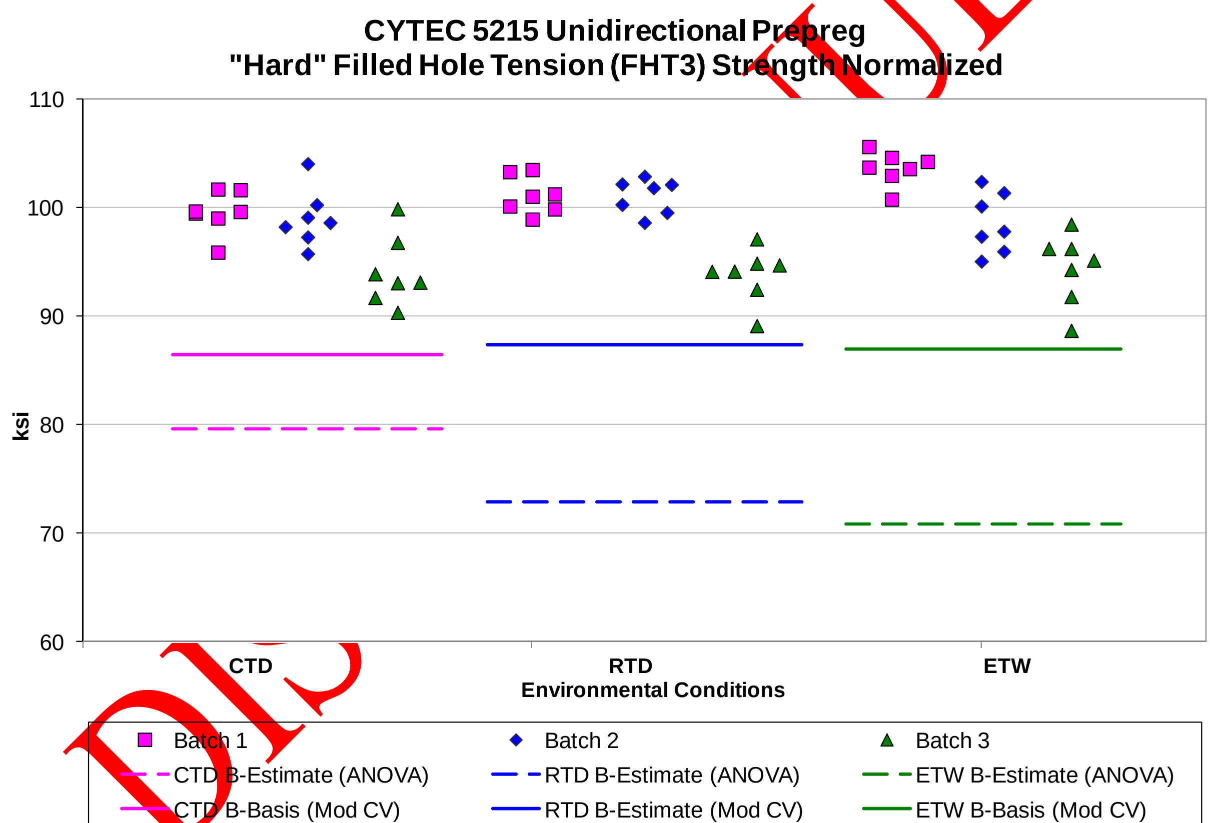

Figure 4-22: Batch plot for FHT3 strength normalized

Filled-Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	97.573	98.661	98.873	97.450	98.597	98.700
Stdev	3.559	3.995	4.597	3.336	3.738	3.751
CV	3.647	4.050	4.649	3.423	3.791	3.800
Modified CV	6.000	6.025	6.325	6.000	6.000	6.000
Min	90.340	89.115	88.682	91.085	88.868	89.891
Max	104.035	103.490	105.614	105.064	103.309	105.199
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value				91.095		
B-estimate	79.623	72.922	70.806		75.921	78.402
A-estimate	66.809	54.545	50.769	86.564	59.732	63.912
Method	ANOVA	ANOVA	ANOVA	Normal	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	86.417		86.957	87.257	88.404	88.508
B-estimate		87.334				
A-estimate	78.471	79.266	78.468	80.372	81.519	81.622
Method	Normal	Normal	Normal	pooled	pooled	pooled

Table 4-32: Statistics and Basis Values for FHT3 Strength data

4.21 Quasi Isotropic (25/50/25) Open Hole Compression (OHC1)

The Quasi Isotropic Open Hole Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The RTD and ETW datasets, both normalized and as-measured, failed Levene's test for equality of variance, so pooling is not appropriate. There were no outliers.

Statistics, estimates and basis values are given for OHC1 strength data in Table 4-33. The normalized data and the B-basis values are shown graphically in Figure 4-23.

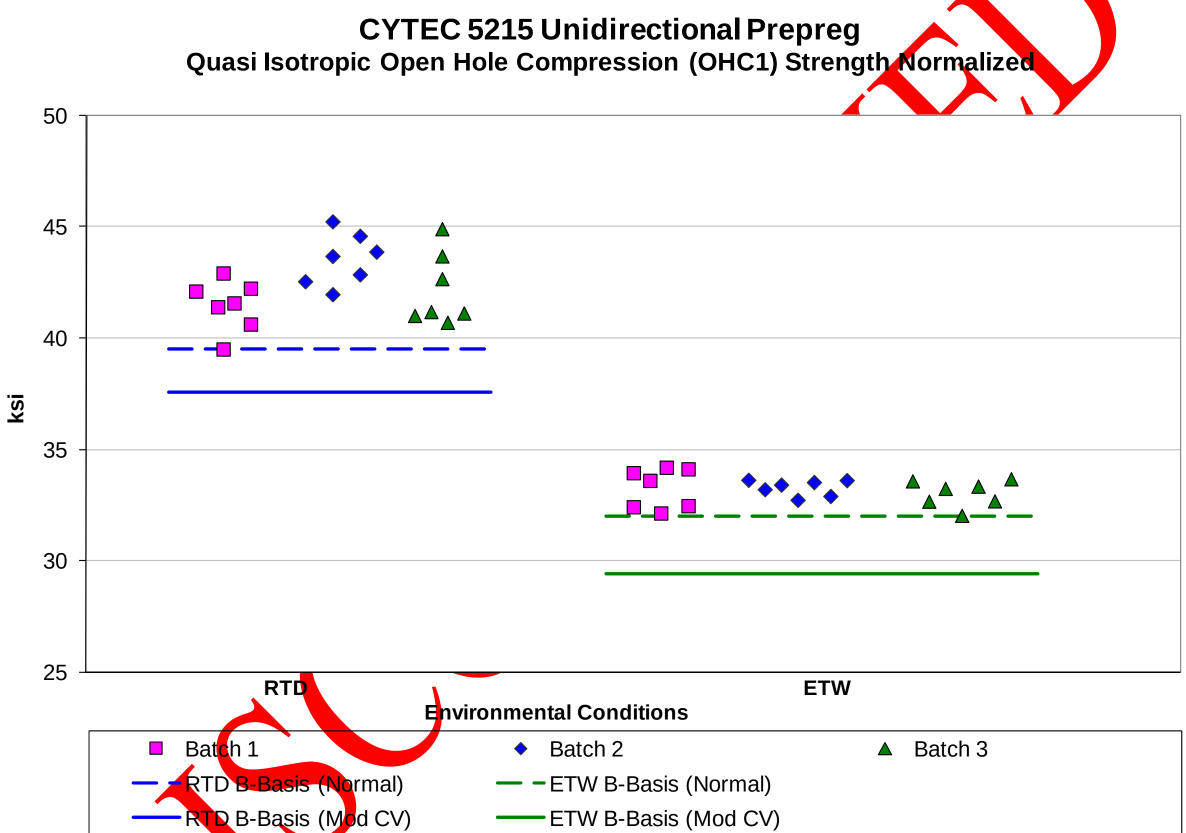

Figure 4-23: Batch plot for OHC1 strength normalized

Open Hole Compression (OHC1) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	42.396	33.195	42.600	33.422
Stdev	1.526	0.630	1.608	0.599
CV	3.600	1.899	3.775	1.791
Modified CV	6.000	6.000	6.000	6.000
Min	39.502	32.032	40.109	32.289
Max	45.233	34.192	45.350	34.213
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	39.489	31.994	39.537	32.282
A-estimate	37.416	31.138	37.353	31.469
Method	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates				
B-basis Value	37.549	29.400	37.730	29.601
A-estimate	34.096	26.696	34.260	26.879
Method	Normal	Normal	Normal	Normal

Table 4-33: Statistics and Basis Values for OHC1 Strength data

4.22 “Soft” (10/80/10) Open Hole Compression (OHC2)

The "Soft" Open Hole Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The OHC2 data had no diagnostic test failures or outliers. Statistics, estimates and basis values are given for OHC2 strength data in Table 4-34. The normalized data and the B-basis values are shown graphically in Figure 4-24.

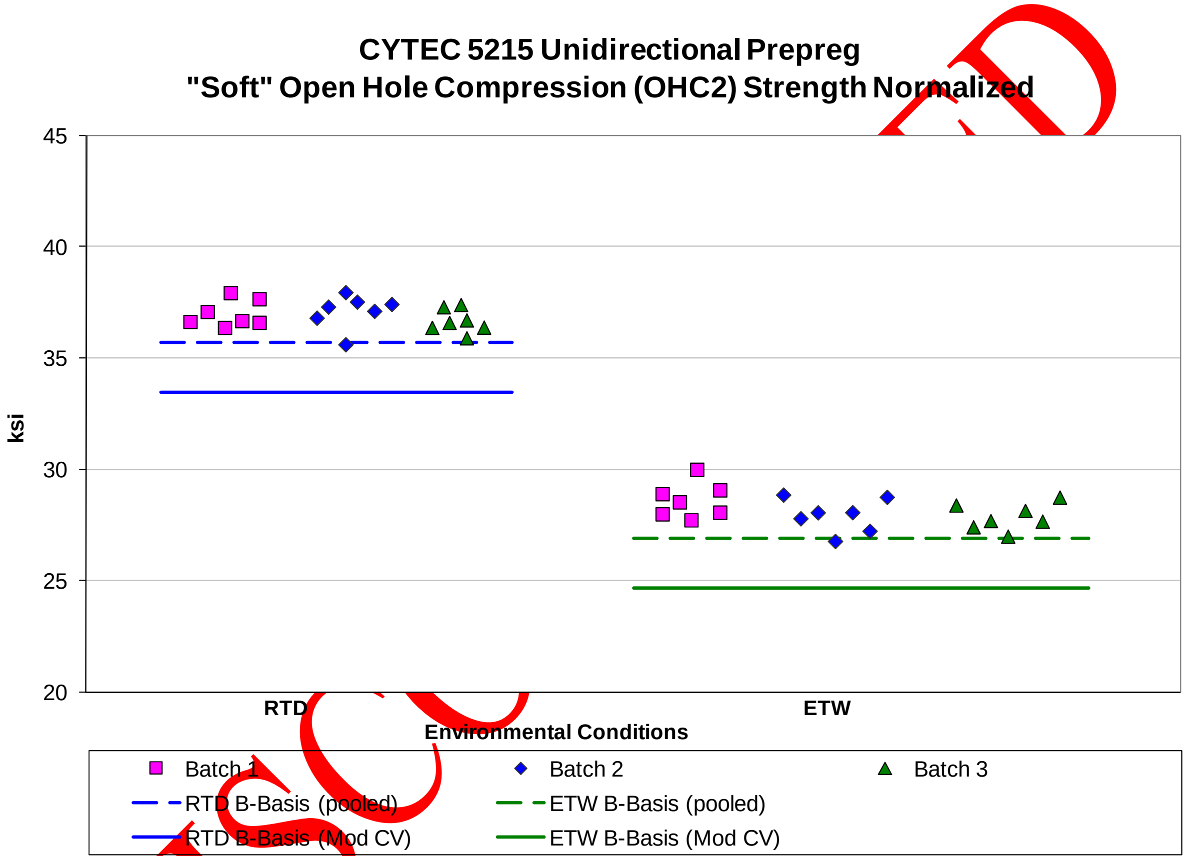

Figure 4-24: Batch plot for OHC2 strength normalized

Open-Hole Compression (OHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	36.919	28.135	36.940	28.130
Stdev	0.627	0.763	0.813	0.763
CV	1.699	2.714	2.201	2.712
Modified CV	6.000	6.000	6.000	6.000
Min	35.613	26.773	35.396	26.801
Max	37.951	29.997	38.663	29.589
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	35.680	26.896	35.542	26.732
A-estimate	34.828	26.044	34.581	25.770
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	33.427	24.643	33.447	24.637
A-estimate	31.025	22.241	31.045	22.234
Method	pooled	pooled	pooled	pooled

Table 4-34: Statistics and Basis Values for OHC2 Strength data

4.23 “Hard” (50/40/10) Open Hole Compression (OHC3)

The "Hard" Open Hole Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The OHC3 data had no diagnostic test failures or outliers. Statistics, estimates and basis values are given for OHC3 strength data in Table 4-35. The normalized data and the B-basis values are shown graphically in Figure 4-25.

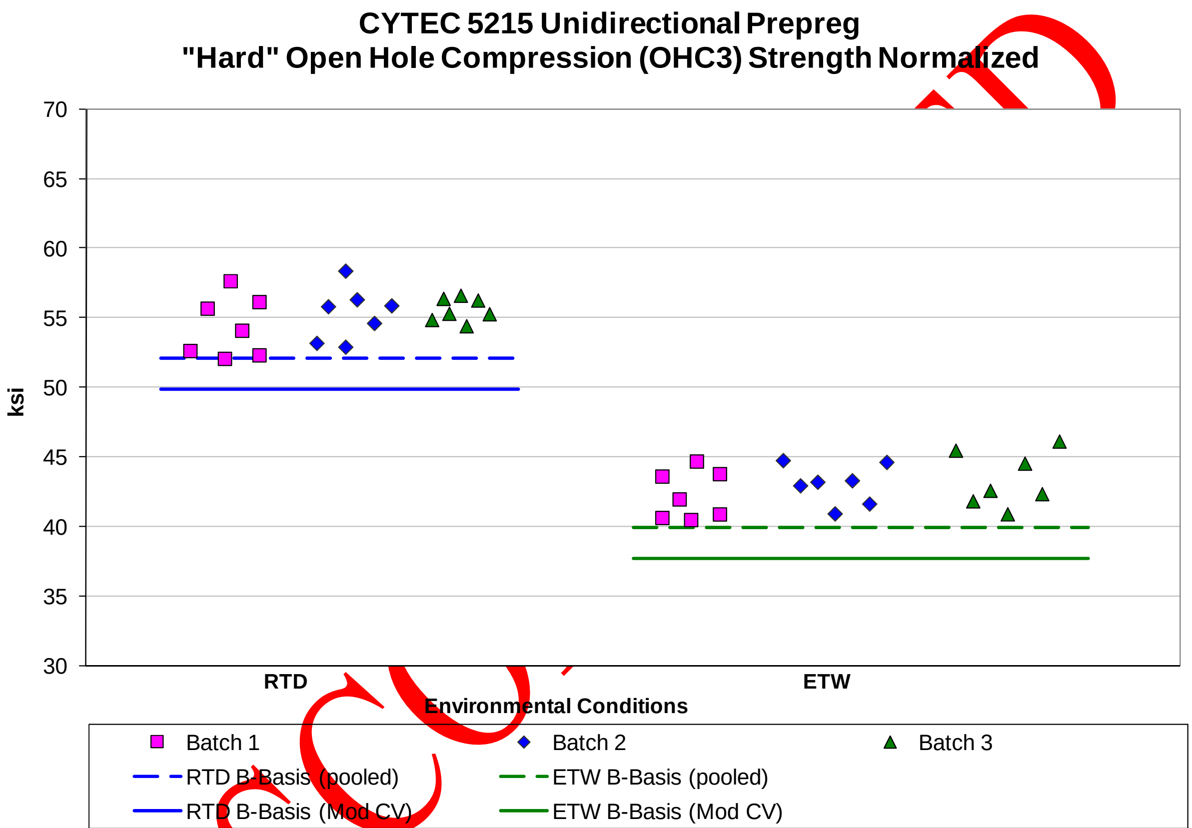

Figure 4-25: Batch plot for OHC3 strength normalized

Open-Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	55.091	42.920	55.501	43.179
Stdev	1.730	1.702	2.062	1.989
CV	3.140	3.965	3.714	4.606
Modified CV	6.000	6.000	6.000	6.303
Min	52.075	40.488	51.258	39.885
Max	58.379	46.135	58.857	46.220
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	52.048	39.877	51.909	39.587
A-estimate	49.955	37.784	49.439	37.117
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	49.837	37.666	50.109	37.786
A-estimate	46.223	34.052	46.400	34.078
Method	pooled	pooled	pooled	pooled

Table 4-35: Statistics and Basis Values for OHC3 Strength data

4.24 Quasi Isotropic (25/50/25) Filled Hole Compression (FHC1)

The Quasi Isotropic Filled Hole Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The as-measured RTD dataset and both the normalized and as-measured ETW failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used for those datasets. The as-measured RTD dataset and both the normalized and as-measured ETW passed the ADK test after applying the modified CV transform to the data. Pooling both environments was appropriate for both the normalized and the as-measured datasets to compute the modified CV basis values. There were no outliers.

Statistics, estimates and basis values are given for FHC1 strength data in Table 4-36. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-26.

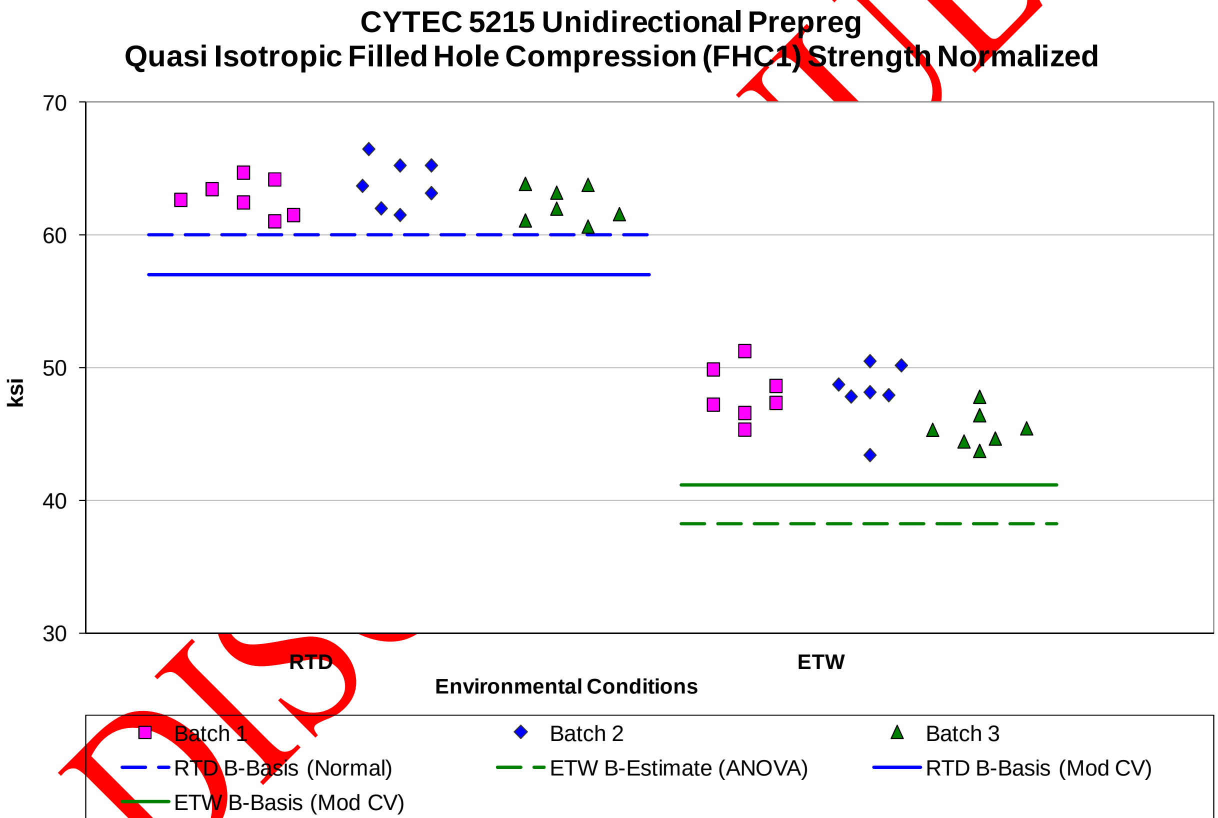

Figure 4-26: Batch plot for FHC1 strength normalized

Filled-Hole Compression (FHC1) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	63.033	47.196	63.276	47.430
Stdev	1.590	2.252	2.199	2.361
CV	2.522	4.772	3.476	4.978
Modified CV	6.000	6.386	6.000	6.489
Min	60.653	43.432	60.040	43.664
Max	66.489	51.267	67.974	51.738
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	60.005			
B-estimate		38.272	52.058	37.392
A-estimate	57.846	31.904	44.050	30.227
Method	Normal	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	56.969	41.132	57.147	41.302
A-estimate	52.799	36.962	52.933	37.088
Method	pooled	pooled	pooled	pooled

Table 4-36: Statistics and Basis Values for FHC1 Strength data

4.25 "Soft" (10/80/10) Filled Hole Compression (FHC2)

The "Soft" Filled Hole Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The as-measured RTD dataset failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used for those datasets. The RTD dataset passed the ADK test after applying the modified CV transform to the data and pooling both environments was appropriate for the modified CV basis values.

There was one outlier. The lowest value in batch two of the normalized RTD dataset was an outlier for batch two but not for the RTD condition. It was an outlier only for the normalized dataset, not for the as-measured dataset. It was retained for this analysis.

Statistics, estimates and basis values are given for FHC2 strength data in Table 4-37. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-27.

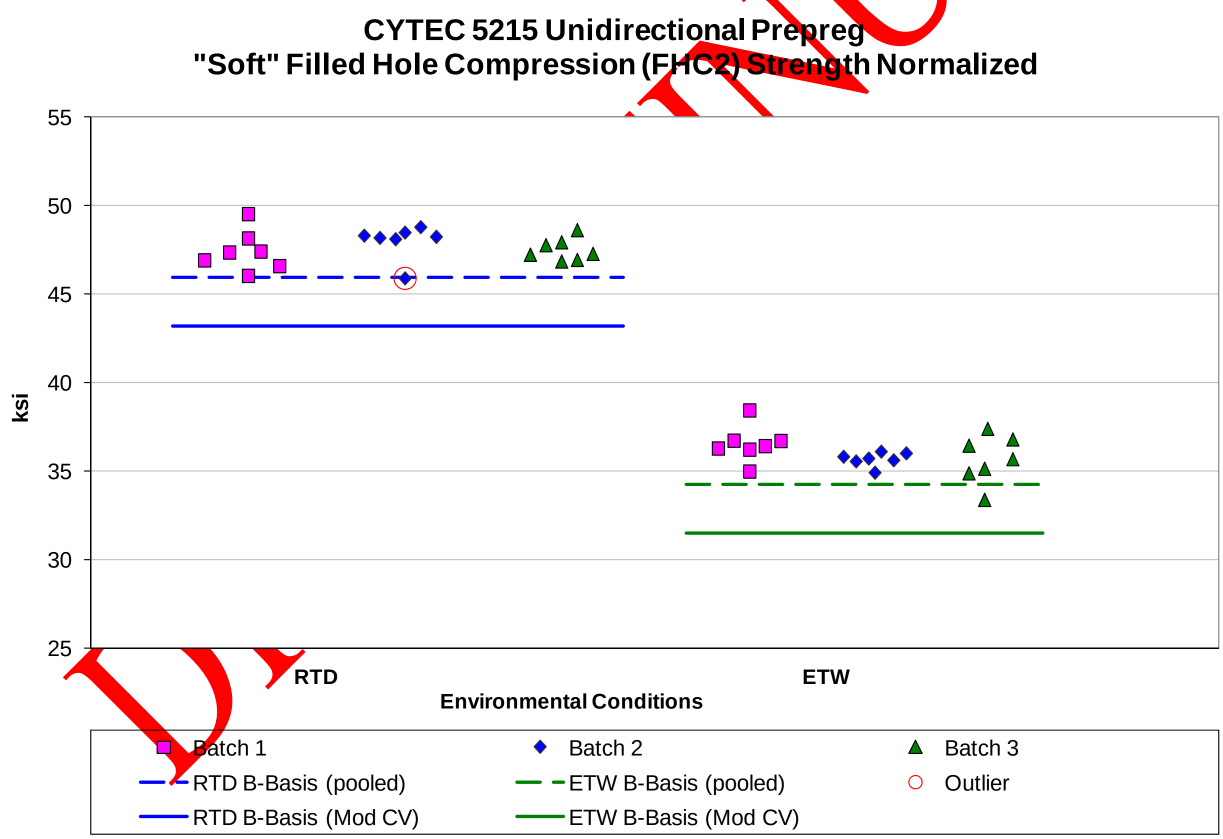

Figure 4-27: Batch plot for FHC2 strength normalized

Filled-Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	47.656	35.968	47.707	35.934
Stdev	0.922	1.040	1.087	1.106
CV	1.936	2.893	2.279	3.077
Modified CV	6.000	6.000	6.000	6.000
Min	45.903	33.383	45.700	32.980
Max	49.529	38.438	49.688	38.018
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	45.912	34.225		33.827
B-estimate			43.184	
A-estimate	44.713	33.025	39.957	32.326
Method	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	43.164	31.476	43.213	31.440
A-estimate	40.075	28.387	40.123	28.350
Method	pooled	pooled	pooled	pooled

Table 4-37: Statistics and Basis Values for FHC2 Strength data

4.26 "Hard" (50/40/10) Filled Hole Compression (FHC3)

The "Hard" Filled Hole Compression data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The FHC3 data had no diagnostic test failures or outliers. Statistics, estimates and basis values are given for FHC3 strength data in Table 4-38. The normalized data and the B-basis values are shown graphically in Figure 4-28.

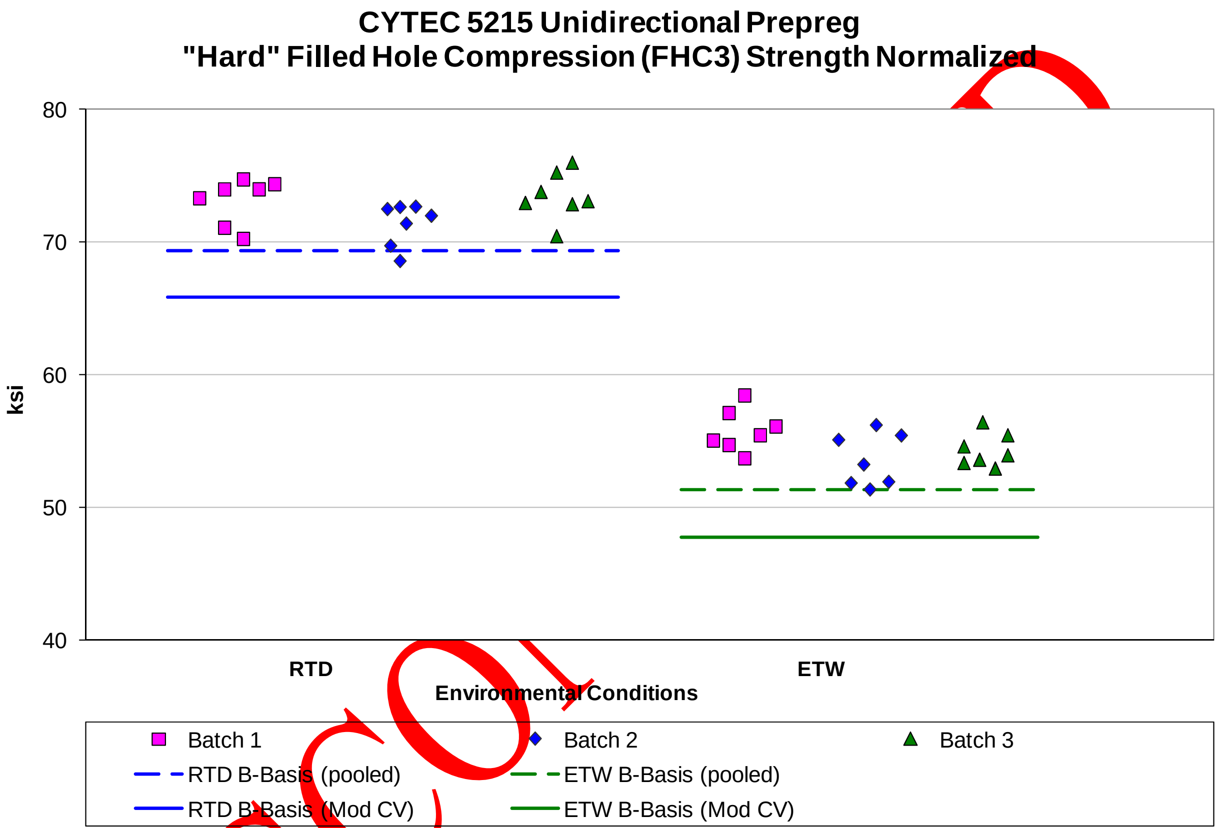

Figure 4-28: Batch plot for FHC3 strength normalized

Filled-Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	72.654	54.577	73.071	54.744
Stdev	1.883	1.810	2.045	1.636
CV	2.592	3.316	2.798	2.988
Modified CV	6.000	6.000	6.000	6.000
Min	68.587	51.365	68.178	50.643
Max	76.002	58.453	76.663	57.869
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	69.379	51.302	69.788	51.461
A-estimate	67.126	49.050	67.530	49.203
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	65.817	47.741	66.202	47.875
A-estimate	61.116	43.039	61.478	43.150
Method	pooled	pooled	pooled	pooled

Table 4-38: Statistics and Basis Values for FHC3 Strength data

DISCONTINUED

4.27 Laminate Short Beam Strength (SBS1)

The Laminate Short Beam Strength data is not normalized. The as-measured ETW dataset failed the ADK test for batch to batch variability, so pooling was not appropriate and the single point ANOVA method was used for those datasets. The ETW dataset passed the ADK test after applying the modified CV transform to the data. The two environments could be pooled to compute the modified CV basis values. There were no outliers.

Statistics, estimates and basis values are given for SBS1 data in Table 4-39. The data, the B-estimates and the B-basis values are shown graphically in Figure 4-29.

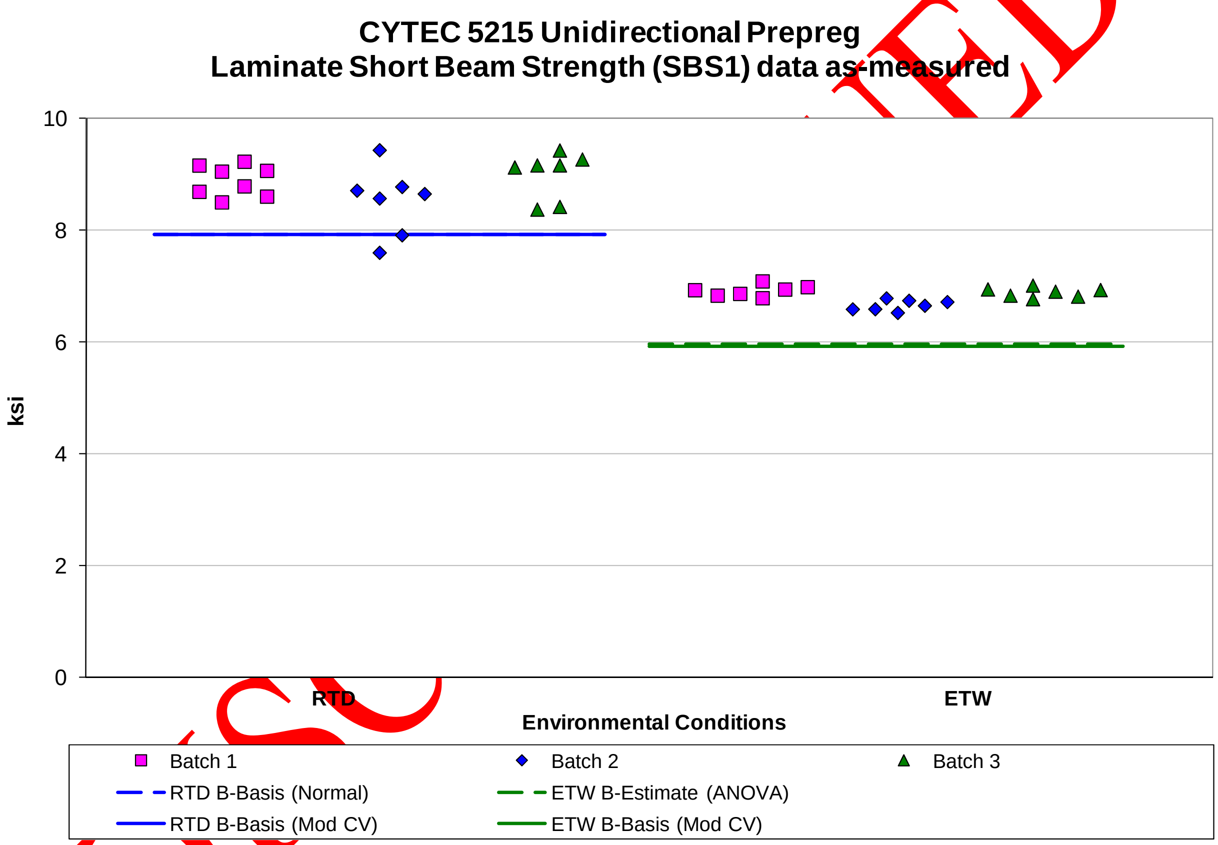

Figure 4-29: Batch plot for SBS1 as-measured

Laminate Short Beam Strength (SBS1) Basis Values and Statistics		
As-measured		
Env	RTD	ETW
Mean	8.802	6.819
Stdev	0.469	0.149
CV	5.324	2.186
Modified CV	6.662	6.000
Min	7.597	6.522
Max	9.431	7.086
No. Batches	3	3
No. Spec.	22	21
Basis Values and Estimates		
B-basis Value	7.918	
B-estimate		5.956
A-estimate	7.287	5.340
Method	Normal	ANOVA
Modified CV Basis Values and Estimates		
B-basis Value	7.907	5.920
A-estimate	7.288	5.303
Method	pooled	pooled

Table 4-39: Statistics and Basis Values for SBS1 data

4.28 Quasi Isotropic (25/50/25) Single Shear Bearing (SSB1)

The Quasi Isotropic Unnotched Single Shear Bearing data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The SSB1 2% offset strength data had no diagnostic test failures or outliers. Pooling the RTD and ETW environmental conditions was acceptable for both the normalized and as-measured datasets.

All of the SSB1 ultimate strength datasets, both RTD and ETW for both normalized and as-measured datasets, failed the ADK test, so pooling was not appropriate and the single point ANOVA method was used for those datasets. All four of those datasets passed the ADK test with the modified CV transformation so Modified CV basis values are provided. Pooling was acceptable for the as-measured dataset but the normalized ultimate strength dataset failed the normality test after the modified CV transform of the data was applied.

There was one outlier. The highest value in batch two of the ETW ultimate strength data was an outlier for batch two, but not for the ETW condition. It was an outlier in batch two of both the normalized and the as-measured datasets.

Statistics, estimates and basis values are given for the 2% offset strength and ultimate strength data in Table 4-40. The normalized data, the B-estimates and the B-basis values are shown graphically for 2% offset strength in Figure 4-30 and for ultimate strength in Figure 4-31.

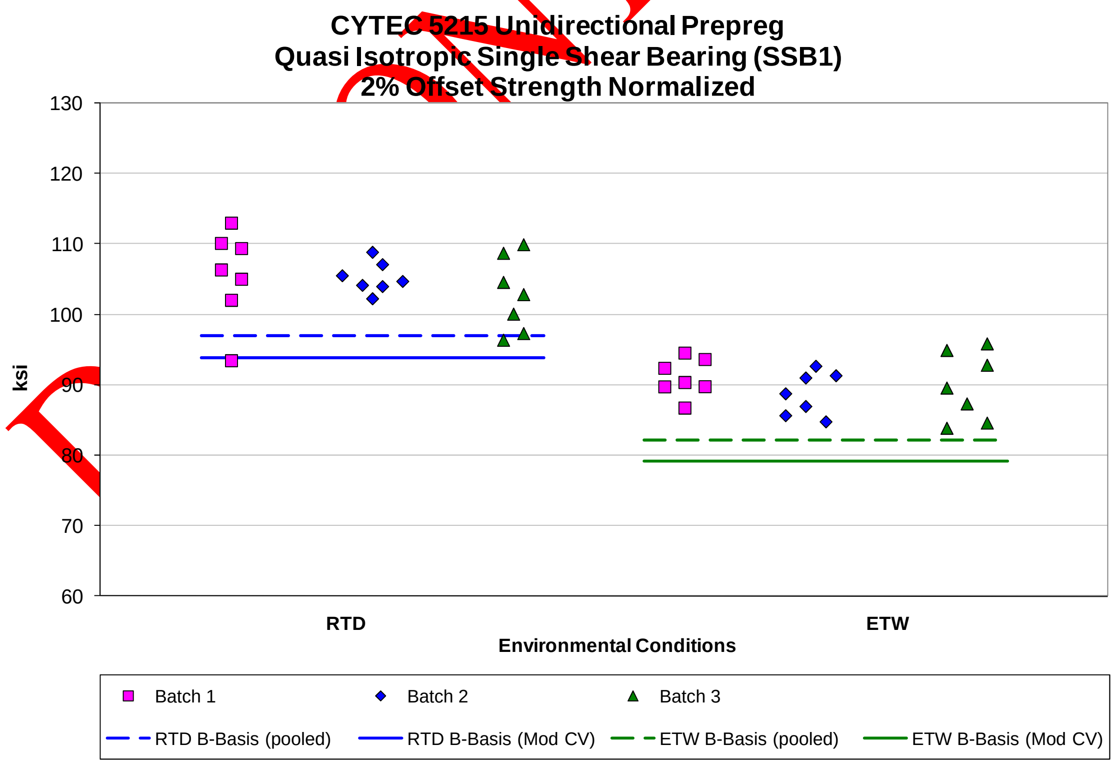

Figure 4-30: Batch plot for SSB1 2% offset strength normalized

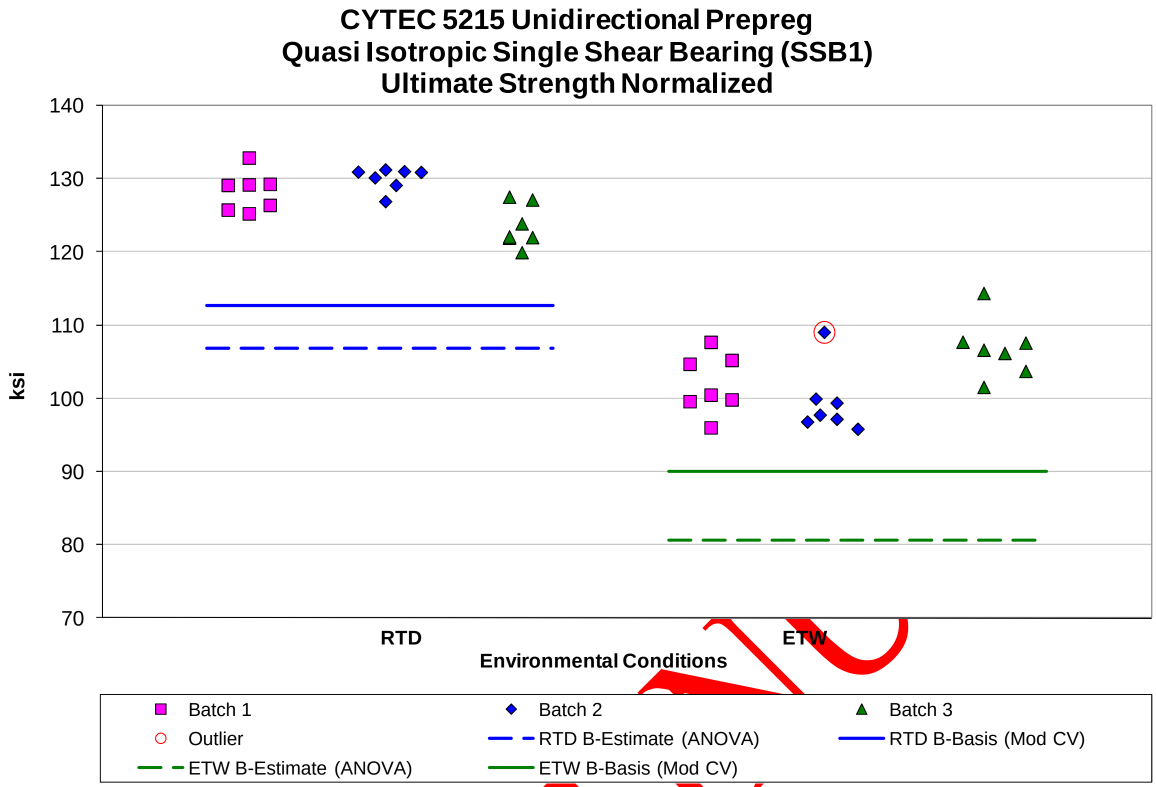

Figure 4-31: Batch plot for SSB1 ultimate strength normalized

Single Shear Bearing (SSB1) Strength Basis Values and Statistics								
	Normalized				As-measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	104.483	89.804	127.172	102.642	105.602	90.685	128.546	103.670
Stdev	4.888	3.584	3.648	5.066	4.549	3.678	3.338	5.600
CV	4.678	3.991	2.868	4.936	4.308	4.056	2.597	5.401
Modified CV	6.339	6.000	6.000	6.468	6.154	6.028	6.000	6.701
Min	93.390	83.809	119.862	95.740	95.556	85.227	121.438	94.770
Max	112.908	95.779	132.764	114.278	112.682	98.294	134.038	117.037
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21	21	21
Basis Values and Estimates								
B-basis Value	96.884	82.204			98.267	83.350		
B-estimate			106.814	80.598			112.769	76.926
A-estimate	91.657	76.978	92.282	64.864	93.222	78.305	101.507	57.836
Method	pooled	pooled	ANOVA	ANOVA	pooled	pooled	ANOVA	ANOVA
Modified CV Basis Values and Estimates								
B-basis Value	93.777	79.098	112.632	89.991	94.954	80.037	115.527	90.651
A-estimate	86.415	71.735	102.274	80.980	87.631	72.714	106.580	81.704
Method	pooled	pooled	Normal	Normal	pooled	pooled	pooled	pooled

Table 4-40: Statistics and Basis Values for SSB1 Strength data

4.29 "Soft" (10/80/10) Single Shear Bearing (SSB2)

The "Soft" Single Shear Bearing data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The SSB2 2% offset strength data had no diagnostic test failures. Pooling the RTD and ETW environmental conditions was acceptable for both the normalized and as-measured datasets.

The SSB2 ultimate strength data for the normalized ETW condition and the pooled dataset for the RTD and ETW conditions failed the normality test so pooling was not acceptable. The non-parametric method was used for the normalized ETW dataset and modified CV basis values were not provided due to the non-normality of the normalized ETW ultimate strength dataset.

There were two outliers. The lowest value in batch two of the 2% offset strength data for the ETW condition was an outlier for batch two, but not for the ETW condition. It was an outlier only for the as-measured dataset, not for the normalized dataset. The highest value in batch one of the ultimate strength data for the ETW condition was an outlier for the ETW condition, but not for batch one alone. It was an outlier only for the normalized dataset, not for the as-measured dataset.

Statistics, estimates and basis values are given for the 2% offset strength and ultimate strength data in Table 4-41. The normalized data and the B-basis values are shown graphically for 2% offset strength in Figure 4-32 and for ultimate strength in Figure 4-33.

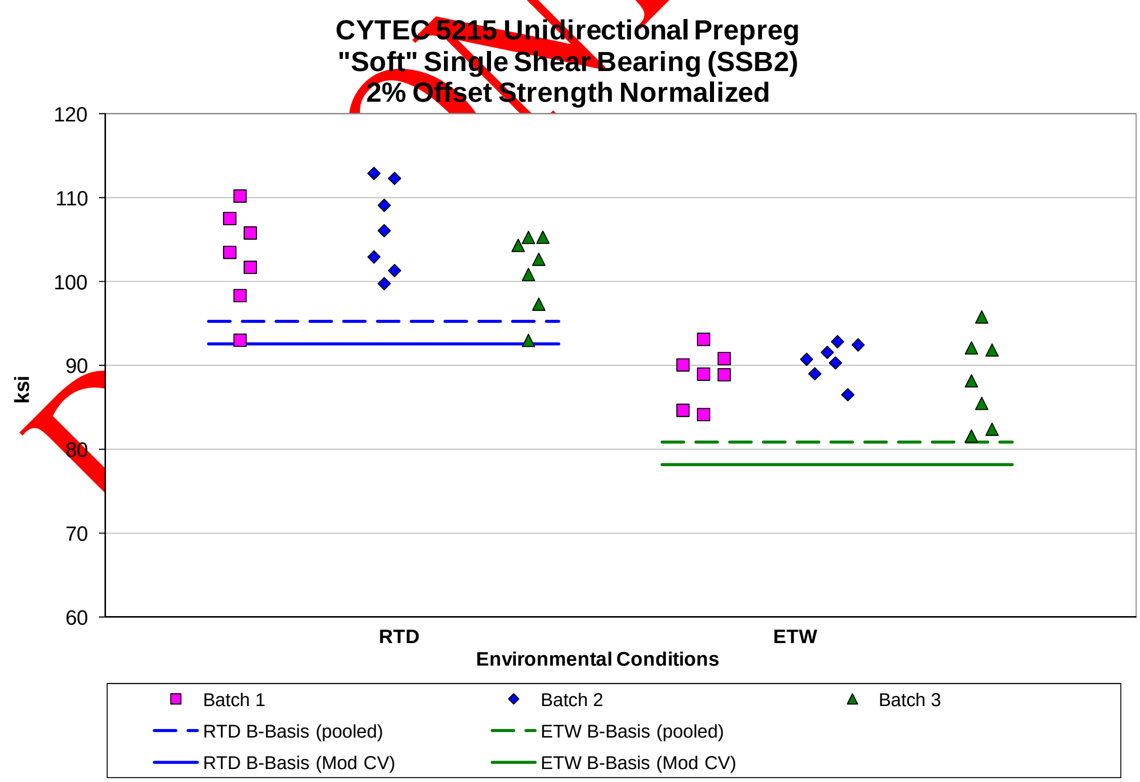

Figure 4-32: Batch plot for SSB2 2% offset strength normalized

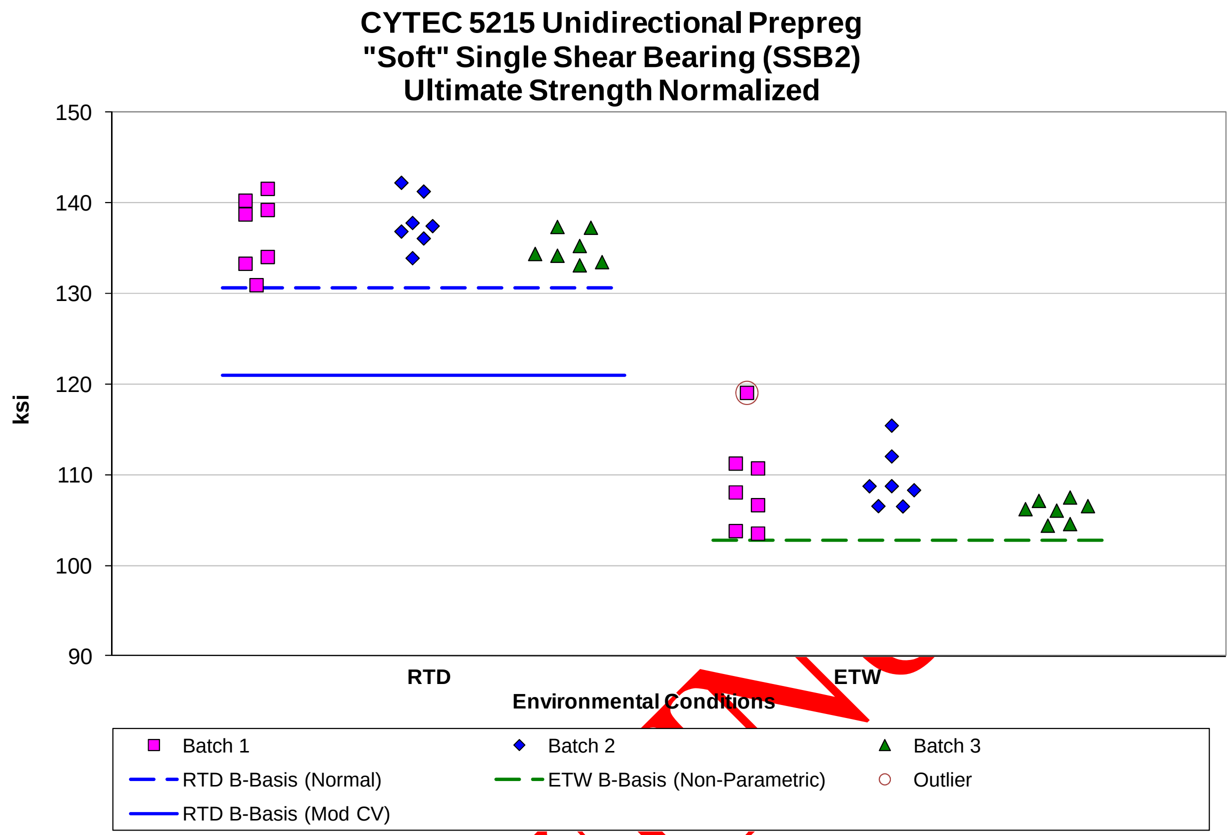

Figure 4-33: Batch plot for SSB2 ultimate strength normalized

Single Shear Bearing (SSB2) Strength Basis Values and Statistics								
	Normalized				As-measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	103.553	89.179	136.531	108.136	105.000	90.129	138.448	109.288
Stdev	5.446	3.765	3.141	3.809	5.294	3.565	2.947	3.490
CV	5.260	4.221	2.300	3.522	5.042	3.955	2.129	3.193
Modified CV	6.630	6.111	6.000	6.000	6.521	6.000	6.000	6.000
Min	93.055	81.641	130.858	103.483	94.637	82.424	133.056	105.010
Max	112.977	95.853	142.147	118.995	112.927	98.105	143.863	118.235
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21	21	21
Basis Values and Estimates								
B-basis Value	95.251	80.878	130.548	102.813	96.997	82.126	132.720	103.560
A-estimate	89.542	75.168	126.282	86.167	91.494	76.622	128.781	99.621
Method	pooled	pooled	Normal	Non-	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	92.562	78.189	120.920	NA	94.060	79.189	125.178	96.018
A-estimate	85.004	70.630	109.801	NA	86.536	71.665	116.052	86.892
Method	pooled	pooled	Normal	NA	pooled	pooled	pooled	pooled

Table 4-41: Statistics and Basis Values for SSB2 Strength data

4.30 "Hard" (50/40/10) Single Shear Bearing (SSB3)

The "Hard" Single Shear Bearing data was normalized, so statistics and analysis results are provided for both normalized and as-measured datasets.

The SSB3 data had no diagnostic failures. Pooling the RTD and ETW environmental conditions was acceptable in all cases. There was one outlier. The highest value in batch one of the 2% offset strength data for the ETW condition was an outlier. It was an outlier only for batch one for the as-measured dataset and for both batch one and the ETW condition for the normalized dataset.

Statistics, estimates and basis values are given for the 2% offset strength and ultimate strength data in Table 4-42. The normalized data and the B-basis values are shown graphically for 2% offset strength in Figure 4-34 and for ultimate strength in Figure 4-35.

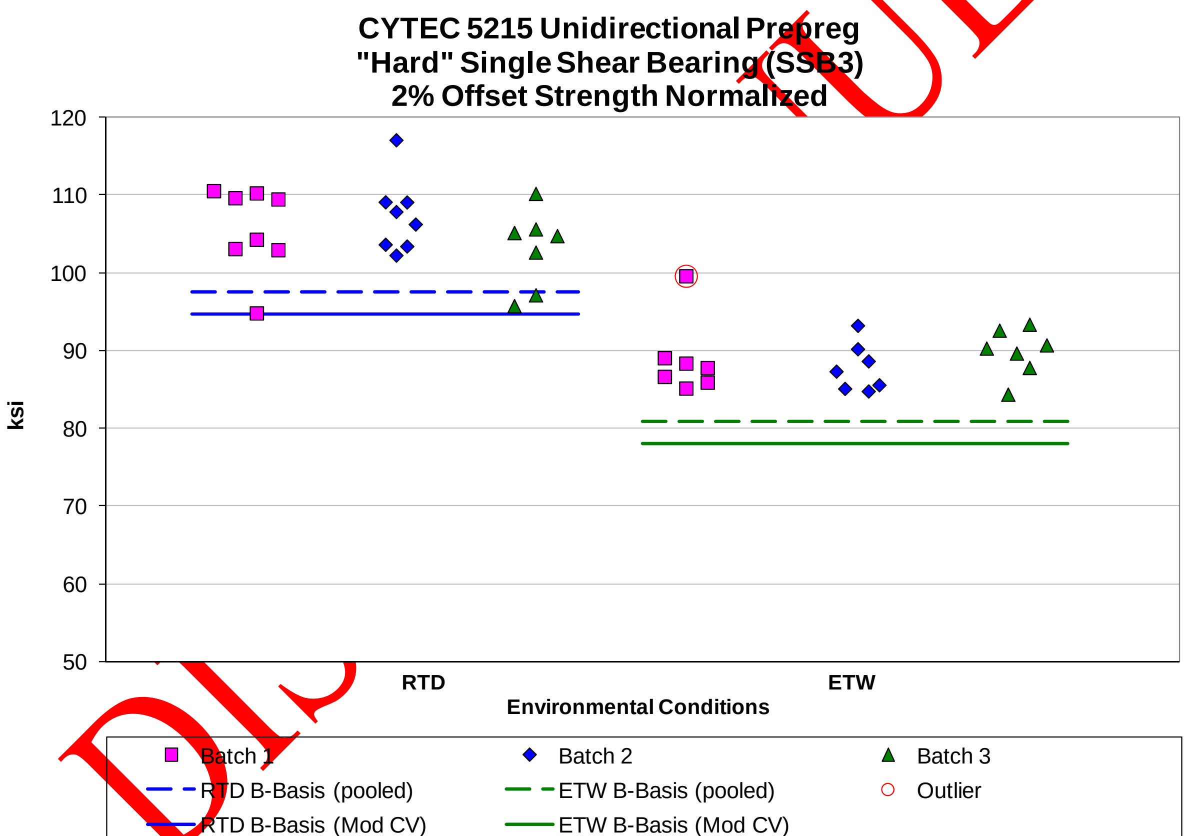

Figure 4-34: Batch plot for SSB3 2% offset strength normalized

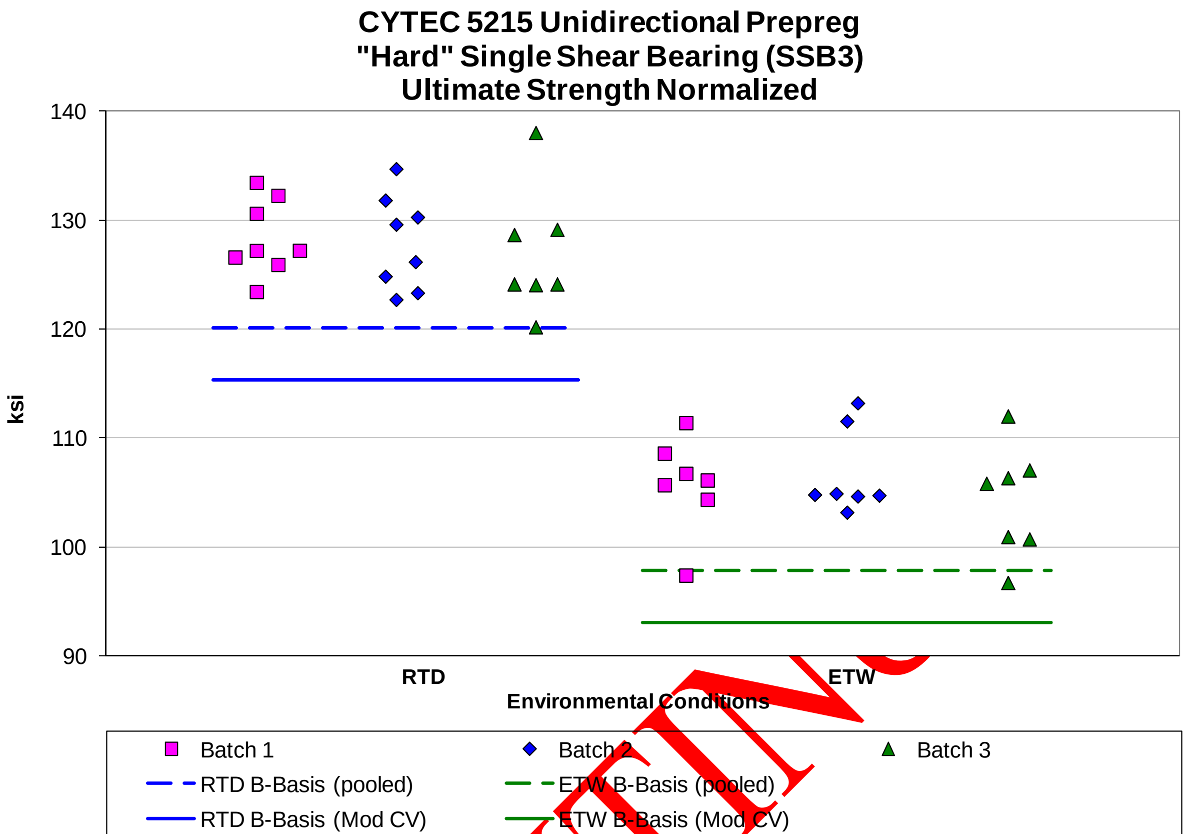

Figure 4-35: Batch plot for SSB3 ultimate strength normalized

Single Shear Bearing (SSB3) Strength Basis Values and Statistics								
	Normalized				As-measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	105.471	88.899	127.773	105.578	107.199	90.507	129.870	107.490
Stdev	5.174	3.679	4.375	4.376	5.043	3.728	4.167	4.544
CV	4.906	4.138	3.424	4.145	4.705	4.119	3.208	4.228
Modified CV	6.453	6.069	6.000	6.073	6.352	6.059	6.000	6.114
Min	94.862	84.395	120.204	96.727	96.170	85.784	123.918	98.704
Max	117.119	99.632	138.039	113.220	119.086	100.588	139.260	117.605
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	23	21	23	21	23	21	23	21
Basis Values and Estimates								
B-basis Value	97.539	80.905	120.101	97.846	99.370	82.616	122.242	99.802
A-estimate	92.040	75.420	114.782	92.541	93.942	77.203	116.954	94.527
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	94.645	77.989	115.331	93.039	96.305	79.527	117.182	94.702
A-estimate	87.140	70.503	106.705	84.435	88.752	71.994	108.386	85.929
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-42: Statistics and Basis Values for SSB3 Strength data

4.31 Compression After Impact 1 (CAI1)

The Compression After Impact data was normalized, so statistics are provided for both normalized and as-measured datasets. Basis values are not computed for this property. The summary statistics are presented in Table 4-43 and the normalized data are displayed graphically in Figure 4-36.

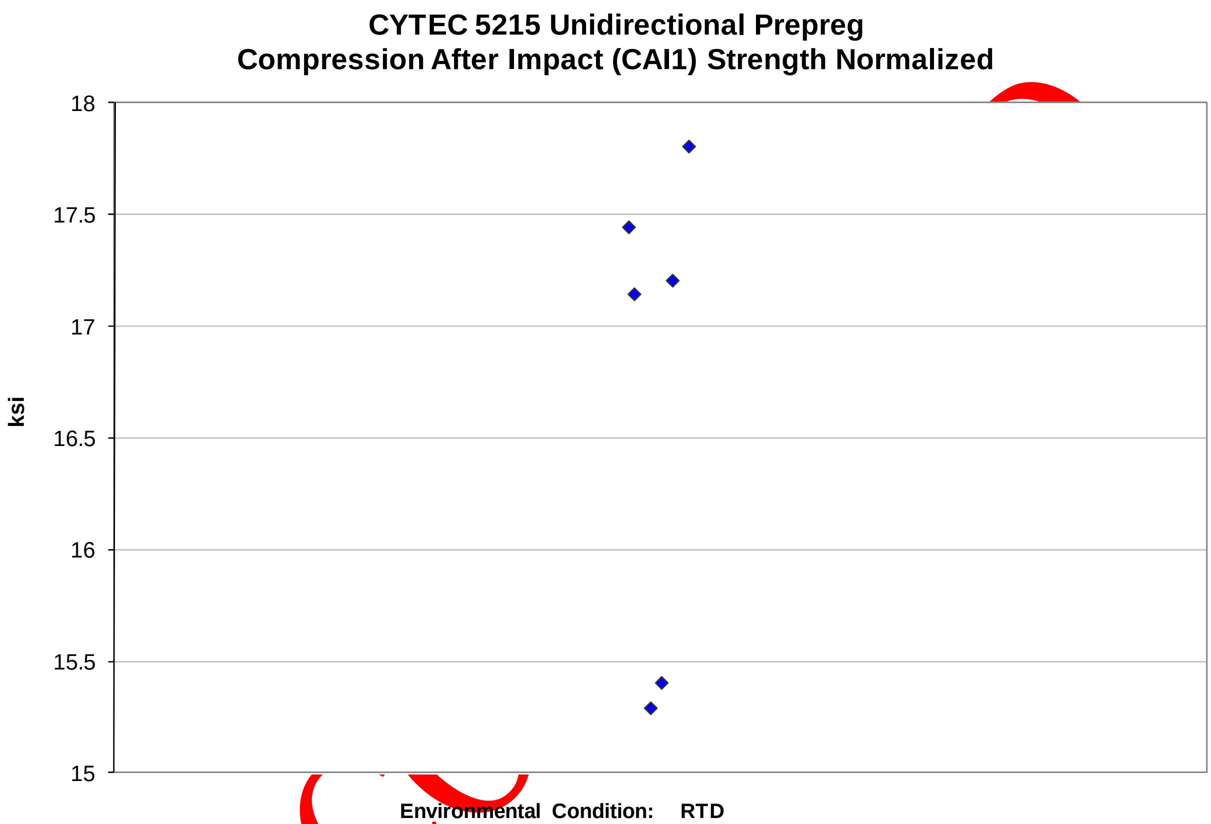

Figure 4-36: Plot for Compression After Impact strength normalized

Compression After Impact (CAI1) Strength Statistics		
	Normalized	As-measured
Env	RTD	RTD
Mean	16.718	17.013
Stdev	1.086	1.069
CV	6.494	6.284
Modified CV	7.247	7.142
Min	15.293	15.517
Max	17.808	18.140
No. Batches	1	1
No. Spec.	6	6

Table 4-43: Statistics for Compression After Impact Strength data

5. Outliers

Outliers were identified according to the standards documented in section 2.1.5, which are in accordance with the guidelines developed in section 8.3.3 of working draft CMH-17 Rev G. An outlier may be an outlier in the normalized data, the as-measured data, or both. A specimen may be an outlier for the batch only (before pooling the three batches within a condition together) or for the condition (after pooling the three batches within a condition together) or both.

Approximately 5 out of 100 specimens will be identified as outliers due to the expected random variation of the data. This test is used only to identify specimens to be investigated for a cause of the extreme observation. Outliers that have an identifiable cause are removed from the dataset as they inject bias into the computation of statistics and basis values. Specimens that are outliers for the condition and in both the normalized and as-measured data are typically more extreme and more likely to have a specific cause and be removed from the dataset than other outliers. Specimens that are outliers only for the batch, but not the condition and specimens that are identified as outliers only for the normalized data or the as-measured data but not both, are typical of normal random variation.

All outliers identified were investigated to determine if a cause could be found. Outliers with causes were removed from the dataset and the remaining specimens were analyzed for this report. Information about specimens that were removed from the dataset along with the cause for removal is documented in the material property data report, NCAMP Test Report CAM-RP-2010-048 N/C.

Outliers for which no causes could be identified are listed in Table 5-1. These outliers were included in the analysis for their respective test properties.

Test	Condition	Batch	Specimen Number	Normalized Strength	Strength As Measured	High/ Low	Batch Outlier	Condition Outlier
LT (UNT0)	ETW	1	C0DPA21BM	266.106	265.974	Low	Yes	No
UNT0				138.923	138.822			
LC (UNC0)	CTD	1	C0DRA214B	263.986	270.936	High	Yes	No
UNC0				100.607	103.061			
LT	CTD	1	C0DJA216B	303.380	299.116	Low	Yes - As meas. No - norm.	Yes
LT	ETW	2	C0DJB219M	392.598	388.059	High	Yes	No
TT	RTD	1	C0DUA211A	NA	3.655	Low	No	Yes
IPS - Strength @ 5% Strain	RTD	3	C0DNC213A	NA	10.995	High	NA	Yes
SBS	ETD	1	C0DQA21AL	NA	8.642	Low	Yes	No
SBS	ETW	1	C0DQA21FM	NA	7.292	Low	Yes	No
SBS	ETW	3	C0DQC11JM	NA	7.442	Low	Yes	No
UNT1	ETW	1	C0DAA11EM	106.034	Not an outlier	Low	Yes	No
UNT3	CTD	3	C0DCC116B	192.128	192.268	High	Yes	No
UNC2	RTD	3	C0DXC212A	Not an outlier	58.655	Low	Yes	No
OHT1	RTD	1	C0DDA114A	73.651	73.624	High	Yes	Yes
OHT1	RTD	3	C0DDC112A	Not an outlier	67.102	High	Yes	No
OHT1	ETW	2	C0DDB11BM	72.105	72.636	High	Yes	No
OHT3	CTD	2	C0DFB118B	120.021	125.049	High	Yes	No
OHT3	RTD	1	C0DFA212A	121.009	Not an outlier	Low	Yes	No
FHT1	RTD	2	C0D4B112A	Not an outlier	66.487	Low	Yes	No
FHT2	CTD	1	C0D5A118B	41.167	41.149	Low	Yes	Yes
FHT2	RTD	3	C0D5C114A	Not an outlier	46.354	Low	Yes	No
FHT2	RTD	1	C0D5A112A	49.746	Not an outlier	High	Yes	No
FHC2	RTD	2	C0D8B112A	45.903	Not an outlier	Low	Yes	No
SSB1 - Ultimate Strength	ETW	2	C0D1B217M	108.970	110.260	High	Yes	No
SSB2 - Ultimate Strength	ETW	1	C0D2A119M	118.995	Not an outlier	High	No	Yes
SSB2 - 2% Offset Strength	ETW	2	C0D2B118M	Not an outlier	86.120	Low	Yes	No
SSB3 - 2% Offset Strength	ETW	1	C0D3A215M	99.632	100.588	High	Yes	No - As meas. Yes - norm.

Table 5-1: List of outliers

6. References

1. Snedecor, G.W. and Cochran, W.G., *Statistical Methods*, 7th ed., The Iowa State University Press, 1980, pp. 252-253.
2. Stefansky, W., "Rejecting Outliers in Factorial Designs," *Technometrics*, Vol. 14, 1972, pp. 469-479.
3. Scholz, F.W. and Stephens, M.A., "K-Sample Anderson-Darling Tests of Fit," *Journal of the American Statistical Association*, Vol. 82, 1987, pp. 918-924.
4. Lehmann, E.L., *Testing Statistical Hypotheses*, John Wiley & Sons, 1959, pp. 274-275.
5. Levene, H., "Robust Tests for Equality of Variances," in *Contributions to Probability and Statistics*, ed. I. Olkin, Palo, Alto, CA: Stanford University Press, 1960.
6. Lawless, J.F., *Statistical Models and Methods for Lifetime Data*, John Wiley & Sons, 1982, pp. 150, 452-460.
7. *Metallic Materials and Elements for Aerospace Vehicle Structures*, MIL-HDBK-5E, Naval Publications and Forms Center, Philadelphia, Pennsylvania, 1 June 1987, pp. 9-166,9-167.
8. Hanson, D.L. and Koopmans, L.H., "Tolerance Limits for the Class of Distribution with Increasing Hazard Rates," *Annals of Math. Stat.*, Vol 35, 1964, pp. 1561-1570.
9. Vangel, M.G., "One-Sided Nonparametric Tolerance Limits," *Communications in Statistics: Simulation and Computation*, Vol. 23, 1994, p. 1137.
10. Vangel, M.G., "New Methods for One-Sided Tolerance Limits for a One-Way Balanced Random Effects ANOVA Model," *Technometrics*, Vol 34, 1992, pp. 176-185.
11. Odeh, R.E. and Owen, D.B., *Tables of Normal Tolerance Limits, Sampling Plans and Screening*, Marcel Dekker, 1980.
12. Tomblin, John and Seneviratne, Waruna, *Laminate Statistical Allowable Generation for Fiber-Reinforced Composites Material: Lamina Variability Method,* U.S. Department of Transportation, Federal Aviation Administration, May 2006.
13. Tomblin, John, Ng, Yeow and Raju, K. Suresh, *Material Qualifciation and Equivalency for Polymer Matrix Composite Material Systems: Updated Procedure,* U.S. Department of Transportation, Federal Aviation Administration, September 2003.